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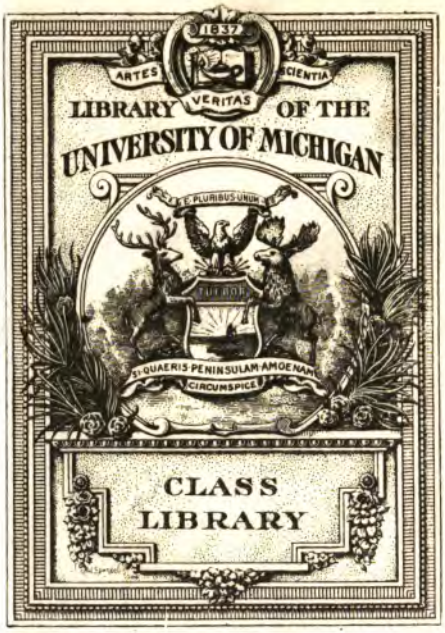

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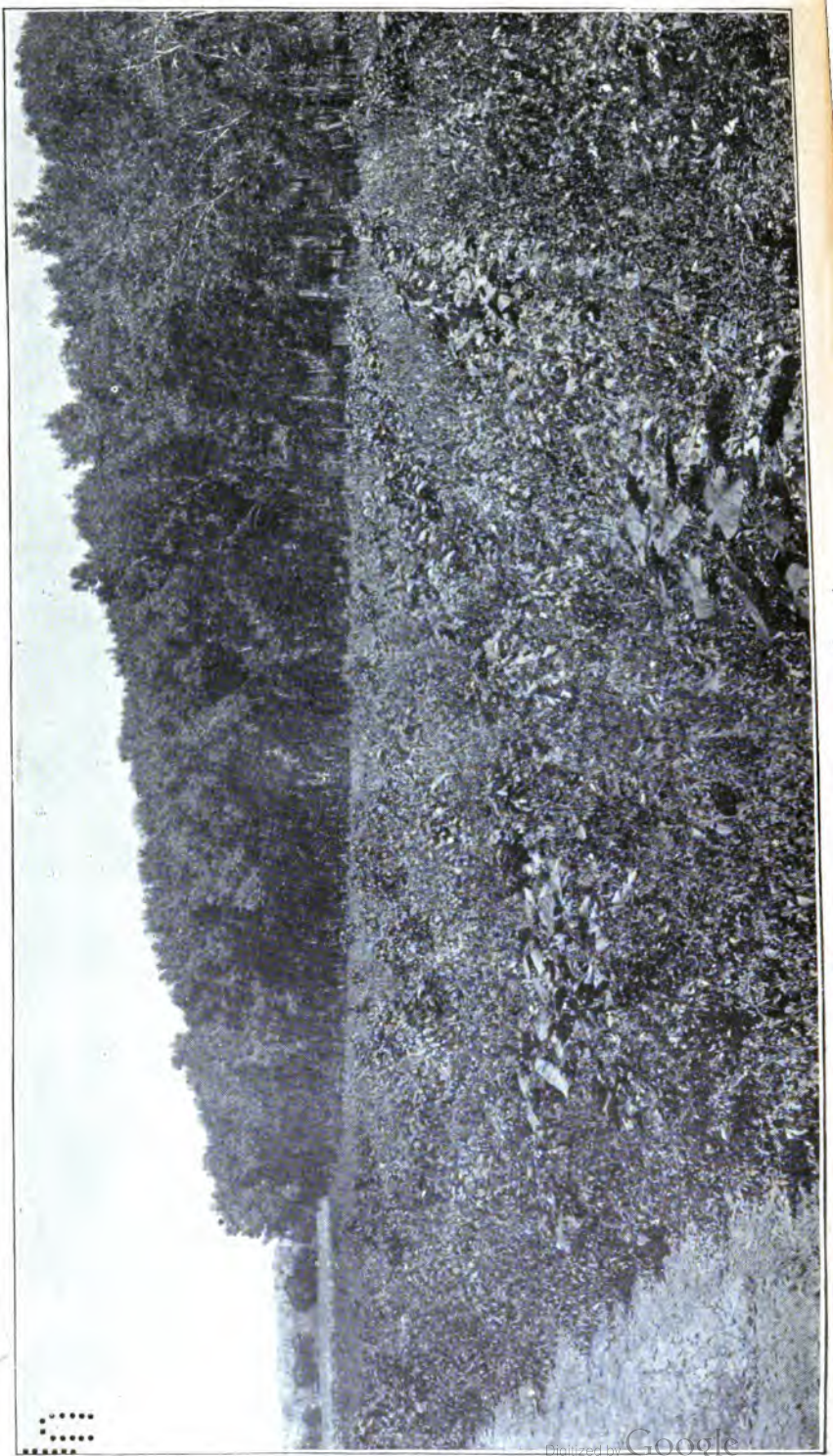

NEBRASKA PLANTATION—PLAT 1.

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BULLETIN No. 18.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF FORESTRY.

EXPERIMENTAL TREE PLANTING IN THE PLAINS.

BY

CHARLES A. KEFFER,

Assistant Chief of the Division.

PREPARED UNDER THE DIRECTION OF B. E. FERNOW, CHIEF OF THE DIVISION OF FORESTRY.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1898.

FORESTRY DEPARTMENT

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF FORESTRY,
Washington, D. C., March 31, 1898.

SIR: I have the honor to submit herewith for publication a bulletin prepared by Mr. Charles A. Keffer, assistant chief, on Tree Planting in the Western Plains, being an account of the experimental plantings made by the U. S. Department of Agriculture.

The direction of this work in detail has been entirely in the hands of Mr. Keffer, whose experience with the conditions of the region for which the experiments were conducted fitted him specially for the task.

The discussion of the principles underlying such planting, which accompany this report, it is hoped will prove an aid to intending tree growers, not only in the West but elsewhere.

Respectfully,

B. E. FERNOW,
Chief.

Hon. JAMES WILSON,
Secretary.

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INTRODUCTION.

Forestry has to deal with forests. Forests subserve two purposes: supply of a most necessary raw material, and amelioration of the conditions of climate and water flow.

In the semiarid and arid regions not only is tree growth established with more difficulty and expense, but except where irrigation can be had in full supply the trees will grow slowly after the vigorous juvenile period of twenty or thirty years, and remain of small dimensions, short bodied, and fit only for firewood.

Protection, then, amelioration of climate, is the principal object of forest planting in these regions. Wood supply is the secondary consideration.

The forests which furnish the enormous quantities of wood material used in this country, amounting in value to $1,000,000,000 in round numbers per year, grow in the humid regions, and will always grow there, because they are more favorable to tree growth, developing larger and better timber, more rapidly and cheaply, and that, too, on nonagricultural soil.

The first interest, namely, our lumber supply, being so infinitely more important, most of the attention of the Division of Forestry was immediately taken up with problems affecting the rational use of our existing forest resources and their recuperation, somewhat to the exclusion of the questions which interest the tree grower of the West.

The only way in which the division could have made itself useful in the latter direction seemed to be in field demonstration, namely, by establishing experimental plantings in which the adaptation of species to the climate and methods of using the same might be tested and object lessons exhibited. Practical difficulties of various kinds and deficiency of funds prevented the inauguration of such work until a plan of cooperation with the State agricultural experiment stations removed at least a part of these difficulties, and the abandonment of other important work furnished sufficient means to attempt this field work. This has now been carried on for three years under many drawbacks, the most detrimental of which is the difficulty of securing properly selected satisfactory plant material delivered in good condition, and of adequate personal superintendence at the various stations during planting time.

While the professors of horticulture who have kindly volunteered to take charge of these plantations unquestionably devote themselves

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to this voluntary duty as zealously as to any other, and have our sincerest thanks for their interest in the same, we are aware that, especially at the planting season, they are so overcrowded with work that only a passing attention can be given to this outside matter; and at the same time wherever directions for field work are to be given from a central office far away from the 10 or 12 stations, all differently situated climatically, the full measure of success can not be expected. The difficulties surrounding the procurement of plant material have been discussed at length by Mr. Keffer in this report.

The objects of these experimental plantings may be briefly stated as follows:

1. Testing adaptability of various native and exotic species in the several regions.

2. Finding methods of establishing such species as seem well adapted, but are difficult to start.

3. Testing the behavior of various species in mixture, and their influence upon one another, as a basis for selecting proper mixtures (mixed planting being recognized as superior).

4. Developing methods of cultivation, more successful or cheaper than those in use.

5. Finding methods of securing plant material most cheaply.

6. Testing influence upon hardiness of locality from which the seed is secured.

7. Demonstrating forestry methods in tree planting.

In spite of the difficulties mentioned, the experiments have been fairly successful and instructive and will become more so as the trees grow. Nor should it be overlooked that, in experiments, failures are just as instructive—provided their cause is discovered—as successes.

More liberal appropriations to place this work upon an adequate basis, commensurate with the interests involved, would produce more satisfactory results.

B. E. FERNOW,
Chief Division of Forestry.

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EXPERIMENTAL TREE PLANTING IN THE PLAINS.

INTRODUCTION.

An effort has been made in this bulletin to bring together a record of experimental plantings, not yet sufficiently extended to be more than suggestive, which have been conducted by the Department of Agriculture during the last two years. It seemed in this connection desirable to give also a brief discussion of conditions affecting tree growth, with special reference to those encountered in the Western plains, where the plantations are mostly located.

The forestless region of America includes all the States between the Mississippi River north of the Ozark Mountains and eastern Texas, and the Rocky Mountains, together with the plateau west of the Rocky Mountains. The possibilities of forest growth in this vast area are yet to be proved. Roughly speaking, any species that thrive in the adjacent wooded regions can be grown in Iowa, the Red River Valley of Minnesota and North Dakota, the Sioux Valley of South Dakota and the eastern counties of Nebraska, and in the more southern States. We know that difficulties of cultivation increase rapidly as one goes westward, but we can not say where the western limit of successful tree culture is. We can not even define the limits of successful agriculture in the plains, for with increased facilities for irrigation splendid crops are now produced where only a few years ago it was thought desert conditions would forever prevail.

It is admitted that forest planting, as a financial investment, will probably be profitable on the plains only in a limited degree. Favorable sites may enable the profitable raising of fence posts and other specialized tree crops, but the growing of timber on a commercial scale can hardly be expected. The quick and sure returns of agricultural crops warrant the farmer in supporting expensive irrigation works in the semiarid West, but we can hardly foresee a time when even an approximate expenditure for the maintenance of a forest crop would prove profitable except for the protection afforded by it. While this is probably true, there yet remains for demonstration the limitations of tree culture within the possibilities of the Western farmer—what species are adapted to his land; what methods give promise of success; what can he do to improve conditions and so make possible not only the growth of useful timber, but also a greater variety of agricultural operations. As has been intimated, the difficulties of tree growing

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increase greatly as one proceeds northward and westward from the eastern forest area. In the eastern border of the plains the planter has almost as great latitude in his choice of varieties as has the dweller within the forest, and he may select timbers of the highest economic value, choosing several kinds, each adapted to specific uses, and planting with them others whose only purpose is to promote the growth of his select trees. As we go westward the possibilities of choice become more and more restricted, until in western Kansas and Nebraska, in the upper Missouri Valley and the high plains of Texas, New Mexico, and Colorado very few species can be relied upon, and these will have to be nurtured and cared for to a degree not dreamed of by the Eastern farmer. The exact limits of choice have yet to be determined. Thus far we must deal largely with generalities and inferences, which become more and more problematical as we proceed westward.

The experimental plantings herein described in detail are given not only as a record of the beginnings of an important work, but as indicating what are believed to be useful mixtures of trees for planting in the West. Sufficient time has not elapsed, even in the oldest plantings described, for final conclusions to be drawn; but the notes on kinds will be found of interest in connection with the experiments, and the whole is believed to afford a basis for selection of trees for the various States included in the treeless area.

While this bulletin has to do primarily with Western planting, it may be found a safe guide in many directions for forest planting within the timbered regions of the country, especially as to general principles involved. Experiments in planting in cut-over lands in the pineries of Minnesota and Pennsylvania have been begun by the Department, but are not yet sufficiently advanced to warrant even a progress report.

CONDITIONS AFFECTING TREE GROWTH.

In common with all plant life, trees require a certain amount of heat, light, and moisture for their development. These elements are so interdependent in their effect upon tree growth that it is almost impossible to consider one without keeping in mind the influence which the other two are constantly exerting. Thus, if we discuss the effect of heat upon tree growth, we are at once reminded that the action of heat and light are inseparable and that the result upon the same species in a moist and a dry region is quite different. It must be remembered that these elements are never dissociated in their influence on plant growth.

Most trees have a wide range of endurance of heat, light, and moisture. The Red Cedar is a striking illustration of adaptability to a great range of conditions. It is found in the swamps of southern Florida, furnishing wood for pencils; on the dry, exposed foothills of the Rocky Mountains, where it is reduced to a mere shrub; along the Platte River Valley in Nebraska, in the northern forests of Maine, and reaches its best development in the limestone soils of eastern Tennessee—an

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immense range of conditions, illustrating well the possibility of adaptation which a single species may have.

All species possess to a greater or less degree the power of withstanding varying conditions, but for each there is an ascertainable degree of heat (and presumably of moisture and light) at which it grows best. In tree culture the character of the soil is important principally (one might say only) in so far as it affects the amount of moisture and heat available for the trees; and the lay of the land—exposure—is also to be considered principally with reference to heat, light, and moisture.

HEAT.

The heat requirement of plants in the open can be controlled to only a slight degree by the cultivator. He may frequently guard against frost by care in the selection of a site for the plantation, and the evil effects of hot winds may sometimes be avoided in the same way; but this is less true in the plains, where there are relatively smaller differences in the elevation of the land than within the forested area.

As a rule, species must from the first be sufficiently hardy to withstand the extremes of heat and cold to which they will be subjected where planted. Hardiness is usually regarded as the ability of a species to withstand cold, but it is quite as important to consider also its heat resistance. The Butternut (*Juglans cinerea*) is not generally hardy in the plains, though native along the streams of Iowa and Minnesota as far north as Minneapolis. It suffers from sun scald in plantations, and hence can not be considered hardy. The Catalpa and Russian Mulberry, while successful in eastern Kansas, fail in the western part of that State in much the same way that they do in northern Nebraska, though the winter climate in western Kansas is but little, if any, colder than that of the eastern part of the State. Light and moisture evidently have an influence in determining hardiness, as well as heat; in this, as in the rate of growth, all three factors are important and can not be dissociated. Classified with regard to their ability to endure cold, the species usually available for planting in the West would stand about as follows, the hardiest being named first:

First group.—Aspen, White Spruce, Yellow Birch, Sweet Birch, Jack Pine, White Pine, Red Pine, Norway Spruce, Red Cedar, Scotch Pine, Austrian Pine, White Elm, Cottonwood, Boxelder, Green Ash (for North Dakota and northern Minnesota).

Second group.—Rock Pine (Bull Pine), Douglas Spruce, Hackberry, White Willow, Black Cherry, Bur Oak, Red Oak, White Ash, Silver Maple (for South Dakota and northern Nebraska).

Third group.—Chestnut, Black Walnut, White Oak, Cow Oak, Hickory, Honey Locust, Kentucky Coffee Tree, Black Locust, Catalpa, Russian Mulberry, White Fir (for south Nebraska and Kansas).

Fourth group.—Pecan, Osage Orange, Shortleaf Pine, Mesquit, Chinaberry (for Oklahoma and Texas).

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Many of the more northern forms named, though not all, will succeed in the more southern localities.

Many more species, both native and introduced, may occur to the reader, but these have come within the observation of the writer and are classified from this standpoint. It must be remembered that light and moisture conditions will greatly influence the action of species, as well as resistance to cold. In general, it may be expected that as one goes westward the conditions affecting growth are more severe, so that species which succeed in the eastern part of the plains may fail entirely in eastern Colorado.

Trees that are not quite hardy while young can sometimes be grown where success would otherwise be impossible by planting them among others of a larger size which may have been set a few years previously, thus affording a slight protection for the more delicate kinds. Several of our most useful species are thus subject to injury from frost during their infancy, becoming quite hardy after the first few years. Even the hardiest species will occasionally suffer badly or be entirely killed by late frosts. At Brookings, S. Dak., almost all the European Larch trees in a plat numbering several hundred were killed by a heavy frost after the leaves were one-third grown. The trees which survived required two years to recover their normal condition. Frost injury to foliage is common to all species in the Northwest, where even the Aspen is not exempt in early spring before the young growth becomes hardened.

A lack of heat affects the growth of trees principally in dwarfing them where they are not killed outright. The Russian Mulberry, which is little more than a shrub in the southern counties of South Dakota, where it is always killed back in cold winters, becomes a good-sized tree in the Arkansas Valley. Bur Oak, one of the largest of its genus as grown in Kentucky and Missouri, presents a stunted appearance in the forests of Minnesota. On the other hand, it has been observed that the Boxelder as grown at Yankton, S. Dak., is larger and more vigorous than the same species at Hutchinson, Kans. The trees in both sites are in bottom land where they have a plentiful supply of moisture. This indicates that too much heat may have a dwarfing tendency the same as insufficient heat. This dwarfing may be turned to good advantage by the grower in his selection of species for mixed planting. Usually in the choice of nurse trees a species is selected that will grow rapidly during the first few years, so as the better to protect the youth of its more delicate nurslings, and then more slowly, so that the protected trees may forge ahead and have the full benefit of all the light for their crowns. It will be for such secondary species only that advantage can be taken of the effects of cold upon the tree growth, and even here other kinds can be found which are not thus harmed, and would presumably be equally good for the purpose in view.

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It should be said that too much heat is quite as objectionable as a too low temperature. Of species not adapted to high temperatures the Boxelder, Aspen, Yellow and Sweet Birch, the Spruces, Larches, and Northern Pines and Hemlock may be mentioned.

LIGHT.

It may be safely assumed that all species of trees make their strongest growth when in the enjoyment of full sunlight, quite free from the shade of their fellows. While this is true, certain species can endure more shade than others, some even being able to pass their entire lives in comparatively dense shade. Almost if not quite all trees can withstand more shade during the first few years of their lives than subsequently; indeed, to some, notably the conifers, such protection is necessary during their infancy. This variability in the amount of shade a species can withstand has given rise to the expressions "light demanding," applied to trees which require full light for their development, and "shade enduring," which are species that can grow for a longer or shorter period in the shade of others. The Cottonwood and the Scotch Pine are good examples of light-demanding trees, and the Beech and Hemlock of shade enduring.

The relative amount of light required by a species changes with heat and moisture; thus in a moist, warm soil an increased amount of shade may be endured and permit the assimilation of the greater amount of food available. One may have striking examples of the interrelation of heat, light, and moisture in the storage of such ornamental plants as the Oleander through winter. These plants are grown in large pots or tubs, and they may be safely kept in a comparatively dark, cool cellar, if at the same time they be given but very little water. If too much moisture be given, the plants will rot, and if they be kept too warm a long spindling growth will result that will weaken the plant almost beyond recovery. If the storage room be light, an increased amount of both heat and moisture will be necessary to keep them healthy.

Because certain species, such as the flowering Dogwood, Beech, Sugar Maple, and Hemlock of the Appalachian region, are found to endure for long periods in the shade of other trees, like the oaks and pines, it must not be assumed that the shade is necessary to their best growth. Neither is it a reasonable inference that the Hemlock can be grown only in the shade because of the disastrous effect upon Hemlock of the removal of associated species. In this case it is the sudden increase of light and the inability of the species to adjust itself to new conditions that frequently results in the death of the Hemlock. Were the pines and hardwoods thinned out gradually, affording a slow change extending over a period of years, the Hemlocks would doubtless be benefited by the increased light.

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Hemlock is much more influenced by moisture conditions than by light, and it seeks northern slopes more because of their moisture than because of their coolness. In a number of city parks where the Hemlock is grown in isolated specimens as an ornamental tree the fact that it succeeds admirably in full sunshine is thoroughly established. So, too, isolated specimens of the flowering Dogwood, the Beech, and other shade-enduring species prove that these trees are able to endure shade better than their fellows, not that they thrive less well in full light.

When trees of equal light requirement are planted together the struggle for light among them results in more rapid thinning than where light-demanding and shade-enduring species are mixed. If the single kind used be light-demanding, weeds and grass soon gain a foothold and rob the soil of much of the moisture which otherwise would be saved to the trees. Illustrations of this are common in the Cottonwood plantations of the West. The Cottonwood is a thin-foliaged, light-demanding species, which does not shade the soil enough to prevent grass growth even where planted close. I have seen plantations of it in South Dakota where the trees were 40 feet high, and cultivation was still necessary to keep the weeds down and conserve the soil moisture.

In making a grove or plantation, varieties of different light requirement should be mixed together, and varieties of equal light requirement should not be mixed. Illustrations of this law abound in wild growths. The Sugar Maple and the Beech are shade-enduring trees, and throughout the Northeastern States they will be found growing well in the shade of such species as White Ash, Black Walnut, and the Oaks and Birches. In even greater degree Hemlock is shade-enduring and is usually found as a lower growth, or "second story," with White and Red Pine towering above.

In the West the only native woods occur along the streams, and the difference in light requirement is less pronounced than in the heavily forested region. All trees there seem more intolerant of shade. Possibly there are fewer cloudy days and the woods are more open, thus surrounding the trees throughout life with more light. But even in the Western woodlands a difference in light requirement is apparent and may be used advantageously by the planter. The Boxelder, Mulberry, and White Elm withstand shade better than the Black Walnut, Green Ash, and Black Locust. The Red Cedar, White Fir, and White Spruce endure more shade than the Pines.

The change in light requirement that comes with age is of great practical importance to the planter, as it enables him to provide shelter necessary in youth to certain species which are, nevertheless, intolerant of shade as they approach maturity. The Bur Oak is decidedly a light-demanding species, but during the first ten years it may be safely surrounded by dense-foliaged neighbors, and, indeed, it will be benefited for an even longer period by receiving light only directly overhead.

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Erect growth will result, with very few lateral branches, thus forming from the first the clean, straight trunk so necessary to high quality in timber.

The Catalpa, though not a shade-enduring tree, retains its lateral branches with such persistence as to require dense-shading nurses to assist it in shedding them. The Scotch Pine, when grown in full sunshine and with plenty of room, as in parks or lawns, seldom forms a straight trunk, but usually divides into heavy branches near the ground, thus making its timber of little value. Close-shading neighbors will correct this fault and result in a straight stem, from which the lower laterals soon fall. Care must be exercised with all the heavy-branched conifers, such as the Scotch, Austrian, Rock (Bull), and Red Pines, not to overtop them with shading trees. They are benefited by side shade, and even that must be reduced as the trees advance; but they are intolerant of shade overhead. The White Pine will endure more shade during youth than the heavier branched Pines named, but it also requires unobstructed light at the top after, say, seven to ten years, and needs full sunshine as it approaches maturity.

Indeed, as was said at the beginning of this chapter, all trees are benefited by full light, viewed from the standpoint of growth. When the use to be made of their timber is considered, however, it may be added that all trees will profit by the formative influence of close planting with shading neighbors that will prevent the light from reaching the lower branches as the trees develop. In the absence of light the foliage is unable to do its work, the branches die from lack of nourishment, and within a few years fall away. The upper part of the crown, meanwhile, is elongated in an effort to reach full light, and thus the stem grows straight and tall, and all the wood laid on the trunk is free from knots. After the stem is well formed additional light should be given the best trees by thinning out the inferior species or specimens, and thereafter increased volume growth will result.

Relative height growth.—In determining rules for mixed planting, the effect of light upon tree growth is intimately associated with the relative height growth of various species.

Not only has each species an average height in maturity, enabling us to make a classification on this basis (White Pine, Tulip, and White Oak being high trees as compared with Boxelder and Mulberry, or Wild Plum and Scarlet Haw), but the growth in height is much greater at one period than at another. Generally speaking, all species make their principal height growth during the earlier part of their lives, the increase in volume of usable material being greater thereafter. But during this time of rapid height growth there is much diversity in the action of species. The White Spruce is very slow in growth during the first years, and its growth thereafter, though much more rapid, never equals that of Scotch and White Pine. The Colorado Blue Spruce is much slower than White Spruce at all stages of its development. As

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observed in nurseries in the lake region, the Douglas Spruce requires about ten years in which to form a leader, during which time it will have grown about 2 feet high; thereafter it resembles the Norway Spruce in its development. Red Cedar grows well from the first, though never a rapid grower as compared with White Pine at its best.

Among the pines that seem especially adapted to the plains the Rock (Bull) Pine is a very slow grower during the first five years and seems never to make as rapid height growth as the Scotch Pine. Scotch and Austrian Pine are similar in growth, the Scotch being a little more rapid; both are better growers than either Rock or White Pine during infancy, but the White Pine under favorable conditions surpasses them at its most rapid period of growth. The White Pine grows slowly in its wild state for the first seven years, then with increasing rapidity to about the thirtieth year, then more slowly, but still at a good rate, to about the eightieth year, by which time the principal height growth will have been attained. The Bur Oak is likewise slow up to about the tenth year, and it never grows as rapidly in height as does the White Pine at its best, but it is a persistent grower over a long period. The Green Ash is a tree of comparatively slow growth, but it maintains about the same rate from the first until it has made its principal height growth. The White Elm is more rapid than Ash or Oak during its first years, and it also continues a vigorous height growth until it approaches maturity. The Cottonwood is a very rapid grower from the first until maturity, as short-lived trees are apt to be. The Boxelder grows with great rapidity until 5 or 6 years of age, and makes its principal height growth by the thirtieth year. It is a medium to small tree when mature. The Catalpa and Black Locust are among the most rapid growing trees during the first few years from seed, but after the tenth year they grow much more slowly, being surpassed thereafter by White Elm. Black Cherry is a rapid and continuous grower, almost equal to the White Elm. Russian Mulberry grows very rapidly the first few years, making many branches and being thus an exceptionally good soil cover. Its period of rapid height growth is about the same as the Boxelder, and like that species it is a medium-sized tree. Silver Maple is a rapid and continuous grower for the first twenty-five years, when it usually begins to fail in close plantation. Black Walnut is somewhat more rapid in growth than Green Ash during the first few years from the seed. At ten to fifteen years Black Walnut will usually equal Boxelder in height, and in favorable soils it has attained a height of sixty feet in twenty-five years, though such rapid growth is exceptional. Honey Locust is a more moderate grower than Black Locust, but fully equals the White Elm and is of similar habit.

These notes, made from observations in Nebraska, Iowa, and South Dakota, may not apply with even approximate truth in the Southwest, where the conditions are very different, but they will serve to call

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attention to an important point in providing the proper light requirement of trees in mixed planting. Such species as Boxelder and Russian Mulberry, which endure more shade than most of the broad-leafed trees that have been tested in the West, by virtue of their comparatively rapid height growth during the first few years, are especially useful as nurse trees, among which other species of more continuous height growth may be set. If the latter be light-demanding they will have overtaken their nurses before much damage can befall them (since all species endure somewhat more shade in infancy than when older), and if they be shade-enduring they will, by their habit of continuous growth, surpass their nurses and thus come into better light conditions as they develop.

The shade endurance of trees is probably less in the plains than within the forest area. A list of trees most likely to succeed in the forestless region, grouped with reference to their light requirement, is given below, the most light-demanding being named first. The ranking is only tentative, and further observations may modify it somewhat, but it is believed to be sufficiently accurate to stand as a basis for determining what species may be planted together:

1. Cottonwood, Aspen, Mesquit, Black Locust.
2. Scotch Pine, Austrian Pine, Rock or Bull Pine, Green Ash, White Ash, Black Walnut, Yellow Birch, Sweet Birch, Black Birch.
3. Red Oak, White Oak, Bur Oak, Tulip, Pecan, Honey Locust, Chestnut.
4. Jack Pine, Catalpa, Silver Poplar, White Elm, Black Cherry, Silver Maple, Osage Orange.
5. Hackberry, Red Maple, Boxelder, Russian Mulberry.
6. Sugar Maple, Beech, Norway Spruce, White Spruce, Douglas Spruce, Red Cedar, White Fir, Hemlock.

Of these groups the first two may be considered light-demanding trees, and the last two shade-enduring, leaving the third and fourth groups midway, but with considerable shade endurance in youth.

In making selections from this list, hardiness and moisture requirement must be kept in mind as well as light conditions and relative height-growth.

MOISTURE.

It has often been claimed that the absence of trees from the plains is attributable to a lack of sufficient moisture, and were it not that so many artificial plantations are growing in what was only a few years ago a treeless region, the hypothesis might be accepted. But when it is recalled, also, that even in the States of Illinois and Iowa, with an average rainfall of from 44 to 32 inches, vast areas were devoid of trees, the theory of itself will not stand.

The minimum amount of moisture necessary for the support of forest growth can not be definitely stated, because other conditions can not

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be dissociated from the moisture requirement, atmospheric movements and soil character being the chief of these. It may be safely assumed that the line of successful tree culture will be moved westward in even pace with the agricultural development of the country, and but little, if any, in advance of it. The clay soil of the plains, protected with but a scant growth of herbage, undisturbed through centuries beneath the burning sun and almost constant wind, compacted by the hoof beats of countless buffalo, can not be as absorbent as it will be when the plow has turned it, and frost has disintegrated it, and the deep growing roots of alfalfa have made it permeable to moisture. Wherever large areas have been brought into cultivation, tree culture has been more successful than before the advent of the plow. The prairies of Illinois, Iowa, and the eastern parts of Kansas and Nebraska with their planted groves fully sustain this view. The area of successful tree culture in the West can be demonstrated only by test plantings. Even should failure attend these at first, it must be borne in mind that the methods employed or the material selected may be responsible for the results quite as much as any lack of moisture.

In the past two years, since the planting experiments herein recorded were begun, the rainfall during the growing season, March to October, at Manhattan, Kans., has been for 1896, 34.24 inches, quite evenly distributed throughout the season; for 1897, 20.51 inches, with only 1.4 inches in August and September. The average rainfall at this station for the months March to October, inclusive, for the past forty years has been 24.02 inches, distributed by months as follows: March, 1.32 inches; April, 2.78 inches; May, 4.08 inches; June, 4.46 inches; July, 4.65 inches; August, 3.52 inches; September, 2.95 inches; October, 2.26 inches: an amount which both in quantity and distribution would lead one to anticipate, what experiments thus far indicate, suitability of soil moisture for quite a number of varieties of trees of the Eastern forest region. At Lincoln, Nebr., the rainfall for the same period in 1896 was 24.22 inches, and in 1897, 21.73 inches, and a reference to the record of growths at that station (see page 59) indicates this to have been ample for the needs of most of the species tested.

At Brookings, S. Dak., the rainfall for the same period in 1896 was 19.1 inches, and for 1897, 20.55 inches, and here again a reference to the measurements of growth (see page 69) indicates sufficient moisture for the needs of the trees. At the stations of Fort Collins, Colo., and Logan, Utah, the tree plats were irrigated, and were therefore independent of rainfall.

SOIL AND SOIL MOISTURE.

The amount of rainfall is not necessarily an indication of the moisture of the soil, and hence of the amount of water available for the roots of the trees. A heavy rain might fall on compact, sun-baked soil, such as is common over extensive areas of the West, and by far the greater part of the water would run off and be lost to vegetation because the

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character of the soil would not permit its absorption. Herein will be found one of the most helpful uses of groves in Western agriculture. The tree tops will protect the surface of the soil, which, after the few years' cultivation given the trees immediately following planting, will become much more absorptive than when protected only by the slight covering of grasses which nature has placed there. The annual crop of leaves falling in the grove becomes an additional absorbent, so that the grove becomes in time a reservoir of moisture, increasing in utility with age. This moisture becomes available to the surrounding fields.

In the sand hills of Nebraska and Kansas, where the soil has but a slight percentage of clay as compared with its large proportion of sand, even after long periods of drought only the few inches of surface soil become dry. Scratch away but a few inches and the sand is found moist to the touch, and this despite an even scantier cover than is found in the clay loams that form the typical soil of the plains. This would seem to establish the fact that soil moisture in any given locality is quite as dependent, if not more so, upon the physical structure of the soil itself as upon the amount of rain falling thereon.

Again, the character of the subsoil plays a very important part in determining soil moisture. There is always somewhere below the surface a moisture-bearing layer. It may be deep in the earth, as are the strata which yield the water of artesian wells, or it may be on a level with the streams, as is the case in the great bottom lands of the Arkansas River. But even where the water-bearing stratum is but a few feet below the surface, if between it and the surface soil a compact clay intervene, the results are almost as deleterious to vegetable growth as though the ground were dry to an unknown depth. These stiff clays are of frequent occurrence throughout the West, and they form a practically impenetrable cover to the water-bearing stratum below, preventing the upward rise of water by capillarity, as would happen in a porous soil. As the dry air is constantly taking moisture from the surface soil by evaporation, unless the loss thus suffered can be replaced the supply becomes reduced to a point where only the lower forms of vegetation can be sustained. The loss of moisture can be supplied in only one of two ways: (1) by application of water to the surface, as by rain or irrigation, or (2) by a rise of water from the lower strata of the soil. These lower strata may secure their water supply from far distant sources, the porous character of the subsoil permitting the transfer of water for hundreds of miles from the place where it first came to earth as rain or snow.

From what has been said it will be readily understood that, while a stiff clay subsoil is unsuitable for trees and should be avoided if possible, it yet remains true that the trees themselves by their growth gradually improve the soil conditions. By shading the surface soil they render it much more absorbent, and their roots gradually penetrate the stiff subsoils, thus permitting moisture to penetrate to a greater depth than would otherwise be possible.

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The influence of the structure or consistency of soils upon their moisture content, and hence upon tree growth, is nowhere more evident than along the Arkansas River. The broad bottom lands of the Arkansas consist of a rich sandy loam of great depth. The porosity of the soil permits the free passage of water—the water level being only 10 to 12 feet below the surface, with no hardpan intervening. The luxuriant growth of planted trees in this moist soil is phenomenal. At Hutchinson, Kans., there are extensive plantations of Hardy Catalpa which average over 20 feet in height seven years from the seed. At Rocky Ford, Colo., in a plantation which had not been irrigated for three years previous to the time it was examined by the writer, the Cottonwoods were growing as luxuriantly as along the bottom lands of the Mississippi in Arkansas.

On the other hand, the effect of a stiff (hardpan) subsoil is equally apparent in the growth of trees. At College Station, Tex., the Brazos Valley is underlaid within 2 feet of the surface with a very stiff blue clay. The native trees on such lands are so stunted as almost to lead one to mistake their identity, and this, too, in a region of heavy rainfall.

Over much the greater portion of the plains the typical soil condition may be stated as follows: A clay-loam surface soil, varying in depth from 1 to 3 feet, dark brown to black in color, of great fertility, underlaid with a moderately stiff yellow or yellowish-brown clay to a great depth. This clay contains considerable sand, and is frequently characterized by small lumps of a calcareous nature, which show white when cut through in digging. It is penetrable by tree roots, though not so easily as is the looser subsoil of the Arkansas Valley. There would seem to be no reason why such a soil, under proper treatment, should not support forest growth. Its moisture-bearing capacity will undoubtedly be increased by the thorough cultivation of extended areas, and thereafter the compensatory action of forest growth will be manifest. Throughout the plains the soil in the bottom lands along the streams is moist for a much longer period than the uplands, and success with trees in the low valleys is comparatively certain. But the great need of groves is on the high lands, where they will act much more effectively as wind breaks, and where the water from the snowdrifts which they catch will be absorbed by the fields. Hence, wherever possible high lands should be selected as sites for groves, even though a slower growth of the trees be secured there.

ATMOSPHERIC MOISTURE.

The great prevalence of winds in the plains region is well known. Their action, generally speaking, is to increase the transpiration from plants and the evaporation of moisture from the soil, and they may thus be considered a hindrance in agriculture, to say nothing of the discomfort they cause. Prof. F. H. King, of the University of Wiscon-

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sin, has published in Bulletin No. 42 of the Wisconsin Agricultural Experiment Station interesting data showing the effect of wind in increasing evaporation, and also the great utility of groves of trees as wind-breaks and crop protectors. Doubtless the ameliorating effects of wind-breaks would be much greater in the plains than in Wisconsin, all meteorological conditions there being more severe.

Series of observations on atmospheric humidity at the several experiment stations show that the relative humidity seldom falls below 50 for more than a day or two at a time, and that such days of extreme aridity of the atmosphere are often followed immediately by periods when the air is of relatively high humidity, permitting a recovery on the part of vegetation from the ill effects of the excessive evaporation which must have occurred during the very dry days. It has been demonstrated that the amount of evaporation from plants is directly dependent upon the available water supply, other things being equal. Of course, a low degree of humidity in the air will tend to increase evaporation, and trees can not be expected to make the vigorous growth under such conditions that is possible in moister regions.

The constant winds are a principal factor in the aridity of the plains. With no obstruction for hundreds of miles, they blow over an area devoid of forests and of large bodies of water. Even in a region of abundant rainfall, such continuous air movement would cause greatly increased evaporation and have a bad effect on plant growth, but with a limited precipitation every means of protection should be employed. It is not to be supposed that trees will grow to the size in the wind-swept plains that the same species will attain within the forest area.

The heavy winds of the plains suggest the planting of forest trees in masses or large groves, rather than in long narrow strips, as was the general practice under the timber-culture law. If ten acres be set aside for a grove, the trees will not only form a better windbreak if planted in a square or a rectangle of but little greater length than breadth, but in their more compact form they will hold the snows better and will themselves suffer much less from the action of the winds. The outer rows of trees will afford protection for the greater part of the plantation. This form of grove is especially useful if it be protected by planting, on all sides and a few rods from its borders, a hedge row of trees that shall serve as a wind mantle. In the North such a hedge will cause the formation of drifts between the hedge and the grove instead of within the grove itself, and the damage by breaking when the snow melts will thus be obviated. Moreover, the water from such melting drifts is largely absorbed by the soil, and thus saved to the farm.

SELECTION OF SPECIES.

In the selection of species for Western planting, it is not always possible for the grower to be governed exclusively by considerations of adaptability to his conditions and utility of the timber. Oftentimes

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he has but a limited range of choice, and in such cases he should consider first of all the suitability of the species to the location. It is a waste of time and energy to plant Cottonwood on high land, except as a roadside tree. While none of the native species in the farther West occur on high lands, all preferring the vicinity of living streams, yet it has been found that some succeed when planted on high lands much better than others. At Ogallah, in northwestern Kansas, in the grounds of the State Forestry Station, Hackberry, White Elm, Black and Honey Locust, Black Cherry, and Green Ash grow well on high lands, their vigor being in about the order named, with Boxelder and Silver Maple somewhat less vigorous. At the Brookings (S. Dak.) Station, Bur Oak and Black Cherry are proving well adapted to high land, as is also Scotch Pine and the native White Spruce of the Black Hills.

Of course, where irrigation is practiced the choice of varieties is only limited by their ability to withstand extremes of heat and cold. It will be readily understood that within the plains—from Texas to North Dakota and from Missouri and Iowa to the Sierra Nevadas—there must be a careful study of the adaptation of species to the soil, climate, and exposure of the particular site to be planted.

In Texas there is a reasonable expectation that the valuable Shortleaf Pine (*Pinus echinata*) will prove useful beyond its natural range in the eastern part of the State, while Rock Pine (*P. ponderosa scopulorum*) should prove useful in the higher lands of the West. This latter species indeed is worthy of trial throughout the plains region, being native of the entire Rocky Mountain region and extending farther east (along the Niobrara, in Nebraska) than any Northwestern tree form. In Texas and the Southwest several other forms give promise of usefulness that will probably not prove hardy farther north than the central part of Oklahoma. The Mesquit (*Prosopis juliflora*) is a native species valuable both for its wood and the forage it supplies for stock, which should prove an excellent nurse for conifers. The Chinaberry (*Melia azedarach*) is a rapid-growing species that has been much used as a shade tree in the Southwest, which may prove useful as a dense shading nurse for such species as Catalpa, Black Walnut, and the Oaks. Both these native forms seed freely and grow readily from seed, and may be used to take the place of such Northern species as Aspen and Boxelder in mixed planting. Among other native forms that will probably prove useful in the Southwest the following may be mentioned as worthy of trial: Osage Orange, Cow Oak, Hackberry, Pecan.

Oklahoma is the border land where one may find a coming together of Northern and Southern species. In the northern part of the Territory such species as are commonly grown throughout the Northwest are planted, though Boxelder and Silver Maple can hardly be called successful. In the southern part the Mesquit is native and the Chinaberry is seen under cultivation. There is offered here a wide range for

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experimentation to determine the adaptability of species to the climate; the settlement of the country being recent, comparatively little planting has been done. Oklahoma, Kansas, southern Nebraska, and southern Colorado should be able to grow a larger variety of trees than the more northern States: Russian Mulberry, Silver Maple, Hackberry, Black Locust, Honey Locust, White Elm, Catalpa, Black Cherry, Cottonwood, Aspen (especially in the West) Black Walnut, Bur Oak (*Quercus macrocarpa*), Red Oak (*Q. rubra*), Chinquapin Oak (*Q. acuminata*), Green Ash, White Ash, Red Cedar, Rock Pine, and possibly White Fir and Douglas Spruce, with Scotch and Austrian Pine for the more northern part of the region. In addition to these a number of other species are doubtless worthy of trial, but only such are mentioned here as are available by purchase or by collection within the region named.

From central Nebraska northward the colder temperature will prevent the use of several species of the above list, notably Russian Mulberry, Black Locust, Catalpa, and Chinquapin Oak, and north of the Iowa line Black Walnut and Honey Locust. In the northern region, however, the Birches and Spruces are added to the list. In the extreme north a very few species are available, the principal ones being Boxelder, Aspen, Yellow Birch, Sweet Birch, White Elm, Red Cedar, White Spruce, Red Pine, Jack Pine, Scotch Pine, and Austrian Pine.

In addition to these trees there are several shrubs and small-sized trees that may prove very useful in Western planting. Among these may be named *Artemisia abrotanum tobolskianum*, a Russian sage brush that has proven a hardy and very vigorous grower from Kansas to the Northwest Provinces of Canada. It attains a height of 6 feet the first season, and makes a useful hedge for catching snow. One year's trial was sufficient to demonstrate its unfitness for use in great quantity as a nurse in close planting, but in wider planting it may perform the office of soil-cover well, and as a wind barrier and snow catcher it will afford great and needed protection when placed to windward of a plantation. Other east Russian species that give evidence of hardiness and vigor are *Elæagnus angustifolia* and *Tamarix amurensis*. The Russian Poplars, which were imported several years ago and which are quite hardy, seem not to be able to resist the heavy droughts that occur in the Northwest. They may prove useful for planting near streams and in moist soil, but for this purpose there are native species of greater value.

The Yearbook of the Department for 1897 contains a list of economic trees suitable for planting in various parts of the country, and this will be found helpful in adding to the varieties above mentioned.

INTRODUCTION OF EXOTIC TREES.

It has been frequently asserted that native trees are better adapted to the conditions of the country in which they occur than those imported from other countries. While experience shows that this is not even

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true in the regions of natural forest growth, in the forestless region we are in the nature of the case forced to employ trees not native, either brought from other parts of our own country, which are climatically similar yet different, or else from foreign countries which may offer species much better adapted to the arid and subarid conditions of our Western plains.

It seemed only proper that at first the adaptability of our very varied native flora be tested with such exotics as had become fairly acclimated, like the Scotch and Austrian Pines, which seem to have done fairly well in some of the Northwestern plains. Last year, however, under instructions of Secretary Wilson, a special effort was inaugurated to find species especially adapted to the arid regions.

In order to do this systematically and with full knowledge of the climatic conditions from which the species came, and with such precautions as are necessary to be observed so as to avoid the simultaneous importation of undesirable pests, Mr. D. G. Fairchild was employed to carry out the following programme, prepared by the chief of the Division of Forestry:

(*a*) Employ a man specially fitted for this kind of acclimatization work, thoroughly familiar, by residence, with climatic conditions of the arid regions or part of them, who is to devote his entire time and attention to this one problem, and give him opportunity to study the field as well as the literature bearing on this problem.

(*b*) Establish (possibly in connection with the experiment stations of Arizona, New Mexico, Colorado, Montana, etc.) trial gardens, where all materials are tested.

(*c*) Collect and plant seeds of plants of all the native tree and shrub flora indigenous to the dry regions of our own country, which have never been tested in cultivation and which probably answer best our needs.

(*d*) After thorough study of literature, and preliminary correspondence with proper persons in foreign countries, let the acclimatizator travel through these countries to collect plant material, becoming familiar at the same time with the climatic similarities and differences of these countries as compared with our own. Some material may be got by correspondence, but this method will prove only partially satisfactory.

(*e*) If properly done and superintended, within four years the most unique and valuable arboreta in the world would thus have been assembled, which would in time answer the question as to the most desirable species for planting in the arid regions.

Before Mr. Fairchild had fairly entered upon his duties it was considered that such a systematic procedure would be desirable in all importations, and the whole matter of plant introduction was placed in his hands.

Meanwhile Prof. N. E. Hansen had been sent on an expedition to Russia, and among the importations secured by him were found the following tree species, some of which were already known, although not extensively tried:

Acer tartaricum.
Artemesia procera.
Artemesia abrotanum.
Caragana (9 species).
Fraxinus mandschurica.
Populus (4 species).
Quercus mongolica.
Salix (6 varieties).
Ulmus campestris microphylla.
Tilia mandschurica.

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Another collector, Dr. Palmer, going into Mexico, the opportunity was embraced to secure from that dry country such valuable species as might be an addition to our Southwestern States, although some of the native species like the Mesquit still await trial under cultivation, which they have never received.

Some years ago the Department imported for these regions the Australian Wattle Trees (*Acacia decurrens* and *pycnantha*), and for the more humid portions several species of Eucalyptus and the Cork Oak. The results seem not to have been very satisfactory (except in California), to a great extent, probably, for lack of attention by those to whom the seeds were sent.

The Mexican importations comprise the following: Axmole, saponiferous; Candelilla, ornamental; *Cæsalpina cacalaco*, tanning; Cobano, timber; *Crecentia alata*, timber and medicinal; Hizlama, medicinal, edible fruit; *Pithscolobium dulce*, tanning, edible fruit, shade; *Pithscolobium sonoræ*, hedge and timber; St. John's Bread (imported from Africa), fruit, forage; *Tabebauena donnel-smithii*, or Primavera, timber.

None of these importations have as yet been planted out. They will at first be taken care of at various experiment stations, as well as at Washington, and it will take several years before a judgment as to the usefulness of these new acquisitions can be had.

HARDINESS.

It has been assumed by many planters that a certain degree of hardiness is inherent in every species as such, and while this may be true to a slight extent it can not be used as a basis for selection. Were it entirely true we should have no need of considering the locality whence our stock came. Red Cedar from Florida would be just as suitable for planting in Nebraska as Platte Valley Red Cedar. It is known that trees can be grown successfully in a locality where the conditions are somewhat, nay, considerably, different from those under which the parent tree grew. Thus the Bald Cypress, whose habitat is the swamps and lowlands along our Southern rivers, is found to grow well in highland, even beyond its natural range. There is a healthy specimen of this tree in the grounds of Prof. E. A. Popenoe in the high prairie overlooking the valley of the Blue River at Manhattan, Kans. It would be unsafe to make hasty generalizations, however. It is known that the locality of the parent tree has a great influence upon the hardiness of its seedlings, and for the West especially, where conditions are uniformly more severe than within the forest regions, seed should be secured from localities most closely resembling that in which they are to be planted. The range of successful seedling growth has yet to be determined, and it is a practical question for experimental determination. It is important to the seedsman, the nurseryman, and the planter. The seedsman should know how far from the place of collection his seeds will prove satisfactory, for of course if the resulting seedlings winterkill or fail to

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withstand summer conditions his trade will be badly affected. Moreover, if seeds can be collected in a locality where they are plentiful and distributed widely a great economy is effected. The nurseryman's reputation is dependent upon the character of his stock as well as upon his personal integrity, so that he should have full knowledge of the influence of the locality of the seed trees upon the hardiness of their offspring. The planter is more interested, perhaps, than either of the others, as the success or failure of his plantation is involved.

Observations have been made on many species. Mr. Robert Douglas reports that the Black Walnut at Waukegan, Ill., when grown from native trees, is perfectly hardy, but seedlings from nuts grown in the southern part of the State winterkill badly at Waukegan. So, too, Douglas Spruce, from seed grown on the western slopes of the Cascades in Oregon, with their moist and mild climate, are not hardy in the Mississippi Valley, while seedlings of the species from trees growing on the eastern slopes of the Rockies, with their dry, rigorous climate, are perfectly hardy. Instances of this kind might be repeated.

To determine the range of this influence of the locality of the parent trees upon hardiness, development, and similar questions, the Division of Forestry has instituted an experiment in cooperation with thirty experiment stations. Seven species of deciduous trees of wide natural distribution were collected at all the stations where they could be obtained, and samples of each lot were sent to the entire list of stations. In this way seed from each locality was grown side by side with seed of the same species from all the other localities, fairly representing the entire country. An opportunity was thus afforded for comparative study. While the experiment has not yet progressed far enough for the publication of results, there are already significant indications which warrant its continuance through a series of years and with many species.

RULES FOR MIXING SPECIES.

The choice of kinds to be planted in any locality is, then, dependent upon hardiness, adaptability to the particular location (high or low land, etc.), availability (ease and cheapness with which they can be procured), economic value of the wood, or especial purpose in view (wind-break only, or post timber, fuel, etc.). The relative height-growth and light requirement are the principal considerations that determine the mixing of species. In some regions the capacity of a species for preserving or improving the character of the soil is also important. The following rules for mixing species are taken from the Annual Report of the Chief of the Division of Forestry for 1886:

RULE 1. The dominant species (i. e., the one that occupies the greater part of the ground) must be one that improves the soil conditions, generally a shady kind.

RULE 2. Shade-enduring (i. e., densely foliaged) kinds may be mixed together when the slower-growing kinds can be protected or guarded against the overshadowing of the more rapid grower, either by planting the slower grower first or in

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greater numbers or in larger specimens, or else by cutting back the quicker-growing ones.

RULE 3. Shade-enduring kinds may be mixed with light-needing kinds when the latter are either quicker growing or are planted in advance of the former or in larger specimens.

RULE 4. Thin-foliaged kinds should not be planted in mixtures by themselves, except on very favorable soils, as in river bottoms, marshy soil, etc., where no exhaustion of soil humidity need be feared, or else on very meager, dry soils, where most shady trees would refuse to grow and one must make a virtue of necessity.

RULE 5. The mixing in of the light-foliaged trees in single individuals is preferable to placing them together in groups, unless special soil conditions make the occupation of certain spots by one kind, which may be better adapted to them, more desirable—as, for instance, the ash in a wet ground (slough). When a slower-growing, light-needing kind is to be grown side by side with a quicker-growing, shady one—as, for instance, Oak and Catalpa—a group of Oaks will have more chance to withstand the shade of the densely foliaged Catalpa than the single individual.

In the experimental plantings of this division a number of mixtures are given which are at variance with the rules above quoted. The purpose in view is to demonstrate the effect of various methods of mixture on the species used, and to make observations upon the growth of the more valuable timber species when surrounded by different shade influences. There are more cloudless days in the plains than in the Eastern forest region, and this change in light conditions may affect the growth of tree species differently. Many combinations have therefore been made, the purpose in view being entirely experimental.

PURE PLANTINGS.

By pure plantings are meant plantations in which only one species has been used. Under the great majority of conditions pure planting is not advisable, particularly so on highland. Where there is a constant supply of moisture, as near a running stream or in bottom lands with a porous subsoil, groves of a single kind of trees will frequently thrive as well as mixed groves.

The same species, especially if a light-needing one, planted where there is a stiff subsoil, or in a drier locality, will grow well for a period of twenty to thirty years, when the trees will die rapidly, and at the time when they should be in the most vigorous health they fail completely, because they were unable to keep out weeds and shade the soil sufficiently to prevent its drying out.

At the Kansas Agricultural College there is a pure planting of Silver Maple, about twenty-five years of age, which began failing about five years ago, and in which there is now hardly a single healthy tree. This grove is on an eastern slope, with rather thin soil on a limestone subsoil—conditions not suitable for the species, which requires a deep, fresh soil.

Mr. C. E. Whiting, of Monona County, Iowa, planted a grove of Silver Maples in 1873, which thrived until they reached an average height of 60 feet. A few years ago they began to fail, and very few

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now remain. These were set in the second-bottom land of the Missouri River, a much more favorable location than the one above cited in Kansas. The failure of pure-planted Cottonwood groves from ten to thirty years old has been so common throughout the West that special instances need not be cited. These are short-lived trees, and under the most favorable natural conditions, as in the immediate vicinity of streams, they thin out rapidly as they approach maturity; so that it is not surprising that they should die young when set in artificial groves.

In the case of longer-lived species, such as Black Walnut, White Elm, the Ashes, and Oaks, pure planting is inadvisable because the trees grow so slowly in youth that it takes them a long time to shade the ground, thus either requiring continued cultivation through several years, an expensive practice, or else resulting in the checking of growth by grasses and weeds. Many species, under the most favorable conditions, do not make a shade sufficiently dense to prevent weed growth. Such trees are unfit for pure planting, not only on this account, but because, having light foliage, the lower limbs continue to develop through a long period of years, and the trunk is thus either very short, or else knotty, either condition impairing the value of the timber.

The only places where pure planting is advisable is in swampy land, where the conditions are such that but few species will grow at all, or on very sterile lands, for the same reason. In all other cases a mixture of varieties is best, in which there shall be species especially adapted to various uses, set among nurse trees which will force them to grow tall and straight.

MIXED PLANTINGS.

Except for comparison, only mixed plantings have been tried in these experiments. The mixtures have been designed to include a varying number of species in different proportions, and have had always in view the light requirement of the several species used. Inexpensive quick-growing material has in all cases formed much the greater part, and the slower-growing species have been placed at greater distances, so that in thinning they would not be disturbed. This cheaper plant material is designed to nurse the more valuable sorts through their earlier years, and insure their becoming established.

NURSE TREES.

Trees which are planted with others in order to influence their growth are called nurses. Their purpose is to create conditions favorable to species that are difficult to establish, by affecting the light conditions surrounding them and by furnishing soil cover. The value of a species as a nurse tree depends not at all upon its utility as timber, but altogether upon its habit of growth. In the treeless region a good

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nurse tree should grow rapidly during the first few years to afford protection as soon as possible and either moderately or very slowly thereafter. Within the forest area rapidity of early growth is less important. As in the human family, the nurse loses its usefulness when its protégé becomes old enough to take care of itself.

Nurse trees have always as their principal object a helpful effect upon those among which they are planted. They may produce the poorest quality of timber themselves, or may even never grow large enough to make timber of any kind, and yet be of the greatest value to the plantation.

The Boxelder, one of our most useful species for Northwestern planting, because shady and most readily grown, is short lived, makes a crooked stem, inferior in quality even for fuel, and is neither a strong nor durable wood, but many valuable species are the better for growing surrounded by Boxelders during their youth, and hence it deserves a place in every plantation in the Northwest.

The nurse tree is of the greatest importance during the first ten to twenty years of the plantation's history. It will frequently, in the first few years, seem to threaten to crowd out the trees which it is intended to benefit, but this is a danger more apparent than real, for if a grove be properly designed, the more permanent trees require just such crowding in order to insure their best development. If the nurse trees are permitted to remain in the plantation too long, or are allowed to encroach upon the main crop, they may become a positive detriment instead of a benefit.

There are two groups of nurse trees—those with thin foliage, making a slight shade, which are principally useful in protecting the infancy of trees difficult to start, but of vigorous aftergrowth; and those having dense foliage, making a heavy shade which will prevent the growth of side branches on their charges by cutting off all the light except that directly overhead, and to serve as soil cover. In the first class are Aspen and Cottonwood; in the second, Boxelder, Silver Maple, Russian Mulberry, and Chinaberry.

It will be readily understood that these two groups of species have a widely different effect, both upon the trees they are intended to benefit and upon the soil. The thin-foliaged kinds will not prevent weed growth, since their shade is so slight that almost all the grasses and weeds are but little affected by it, and they will thus be of slight benefit in shortening the period of cultivation. But they create a condition seemingly favorable, especially for the conifers, in the plains where the excess of bright sunshine is in striking contrast to the native environment of most young evergreens.

Within the White Pine region, when fire has destroyed the forest, it has been observed that the first trees to appear in the burned district are Poplars (Aspen) and Birches, and when these have attained a height of from 5 to 10 feet many young Pines and other evergreens

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may be found growing in their shade. In the denser shade of mature Hemlock, for instance, comparatively few seedling Pines are found. The seed would germinate there, but the plants could not thrive in such dim light any more than they could in the full sunshine.

Acting upon this observation, plantings were made the past season of Aspen and Birches at all our stations, having spaces at intervals of 8 to 12 feet, in which various species of Pine, Spruce, and Fir will be planted when the nurse trees have from one to three years' start. So far as known this is the first experiment of this kind that has been undertaken in the West.

The Aspen (*Populus tremuloides*) should be a better tree for this purpose in the plains than either the Cottonwood (*Populus deltoides*) or the Birch (*Betula lutea*), because its shade is the least dense and its vigorous growth lasts a shorter period. The Birch, which in its native woods has a rather slender habit of growth, in the bright sunshine of the plains becomes stalky and densely leafed. This has been observed at the stations in South Dakota and Nebraska, and may result in a totally different effect upon the conifers to be set with it than has been observed in the natural forests. Indeed, it may be said in passing that the intense light of the plains region, no less than the widely differing soil and moisture conditions, is apt to have a pronounced effect upon the development of species native of cloudy, moist localities.

Other light-foliaged trees that may serve equally well as nurses, especially in the Southwest, are the Black Locust, also called Yellow Locust (*Robinia pseudacacia*), and the Mesquit (*Prosopis juliflora*). These species have the advantage of being valuable timber trees.

The Black Locust is like the Cottonwood in being a gross feeder, and this habit may prevent the use of either species as a nurse for conifers, which in several species are slow to become established. Like the Cottonwood, too, it is a thin-foliaged, light-demanding species. So far as known the Mesquit has never been tested in artificial groves.

The use of quick-growing, densely shading nurse trees has been more thoroughly tested, and results have already been reached which fully warrant the practice. They are especially valuable where broad-leafed trees only are planted, and as the price of evergreens has hitherto prevented their extensive use in the plains, the employment of dense-shading nurse trees is worthy of somewhat extended discussion.

A plantation of Green Ash or White Elm, two of the most widely successful species that can be grown in the plains, can best be established by covering one-half to three-fourths of the ground with Box-elder or Russian Mulberry, and setting in the desirable Ash and Elm at regular intervals. Planted by themselves, Ash and Elm will each make more vigorous growth than when surrounded by the other species, because they are both light-loving trees, and in the full sunshine they will throw out many branches, spreading their tiny crowns

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in much the manner of the fully developed tree. But despite this more luxurious growth they do not make sufficient shade to protect the soil beneath them, and unless cultivation is thorough there will soon be a compact sod of the strong-growing prairie grasses among the trees that will take from them much of the soil moisture and thus materially check their growth. The same thing is true of all the more valuable broad-leafed trees. The Black Cherry, although a dense-shading species while young, does not grow rapidly enough to be used as a nurse tree, and is too expensive. Catalpa, a good shade-making tree in midsummer, is about the last species to leaf out in the spring and the first to drop its foliage in autumn; moreover, its branches are so persistent that it needs the help of a denser-shading variety to check lateral growth at the earliest possible moment.

The other economic species that are easily obtainable in the West—the Oaks, Chestnut, Walnuts, Hickories, Tulip, and Locusts—will all profit by the protection or formative influence of a good nurse during the first ten years after planting.

The conifers that have been planted with dense-shading nurse trees in the West have succeeded well, and have stood more shade than one would suppose. At the Brookings (S. Dak.) Station White Spruce and Colorado Blue Spruce are completely overtopped by the nurse trees which surround them and show no distress, while Scotch Pine and European Larch fully equal in height the Boxelder and Maples with which they were planted ten years ago.

From the standpoint of the farmer, dense shading nurse trees are useful because they reduce the period of cultivation and the consequent cost of the plantation, and greatly increase its effectiveness as a wind-break. To accomplish this purpose, the nurse must be a rapid growing or spreading species that shall completely shade the ground, when planted 4 by 4 feet, at the close of the second or third season.

Using such a tree, it will be found that the second year cultivation will be somewhat interrupted by the growing lateral branches, while during the third year not more than half the cultivation required the first season will be necessary, if any, and thereafter there will be no need of cultivation whatever, provided the density of the crowns is preserved. Contrasting this with the care of a grove in which light-foliaged species, such as Cottonwood or Aspen, form the majority of the trees set, or one in which the trees are planted at greater distances, it will be seen that continued plowing is necessary to keep down the weeds and grass.

It may seem unnecessary to keep the soil free of weeds and grass, but it should be remembered that the most important factor in all cultural operations in the drier parts of the country is the saving of soil moisture. With a limited rainfall and excessive evaporation, the farmer is compelled to save to his plants, by every device in his power, such moisture

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as comes to his fields. He can not afford to permit grass and weeds to rob his young trees of moisture any more than he can permit them to rob his corn. When once the trees have completely shaded the ground, no other growth is possible.

Among the quick-growing, densely foliaged trees only one species seems especially valuable as a nurse tree in the colder parts of the West, and that is Boxelder. Farther south the Silver Maple and Russian Mulberry may be used, while in Texas it is thought the China Berry will prove a valuable nurse tree. The Umbrella tree (*Melia azedarach var. umbellifera*) should prove even more useful in the same region.

Artemisia (*A. abrotanum tobolskianum*) has been planted as a nurse in various mixtures at several of the Western stations. It is perfectly hardy, but is an extremely vigorous grower, and cuttings when less than two years planted have grown so rapidly that it has been necessary to cut them back severely to prevent them shading out the more valuable trees. Artemisia is a tall-growing bush, sending up many stems from the collar, and it has been found necessary to remove all the stems but two in their second year. It grows readily from cuttings, and is sure to prove useful as a surface wind break, though it will probably prove too rampant a grower for use as a nurse. As a nurse it will have to be handled with the knowledge that in the first season it will spread enough to cover 6 square feet of ground, but after that not gaining much in size.

Elæagnus angustifolia, the Russian Wild Olive, has been recommended as a nurse tree for use in the Northwest, being perfectly hardy, as also has Tamarisk (*Tamarix amurensis*), a Russian form of the well-known ornamental shrub, though the latter seems hardly a dense enough grower to be as useful as Boxelder.

THE USE OF EVERGREENS IN WESTERN PLANTING.

It will be observed in the experiments hereinafter noted that in all the plats set in 1897 spaces were left to be filled in with evergreens. No one questions the great value of this class of timber trees for grove planting in the West. The fact that they retain their leaves throughout the year makes them the most useful species that can be employed in making wind-breaks, while their erect habit of growth and strong light wood gives their timber peculiar value in farm construction. The principal difficulties heretofore experienced in western conifer planting have been the high price of stock and the poor average stand secured. Doubtless the cause of the high prices charged by nurserymen for evergreens has been the small quantity of such stock demanded by the market. In nursery operations a great quantity of trees can be grown for very little more money than a small quantity, and if the nurserymen could be assured of a large market, there would

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be a proportionate decline in prices. The Department of Agriculture purchased in the aggregate 885,000 conifers during the spring of 1897. The trees were all seedlings two to three years old, except such as had to be dug in the forests, which probably ran from three to seven years. The standard nursery varieties, such as White, Scotch, and Austrian Pine, White and Norway Spruce, cost from $2 to $4 per thousand. Nursery-grown Douglas Spruce were secured at $6 per thousand, and wild seedlings of Red Pine for $12.50 per thousand. It must be understood, of course, that these prices, so much below the rates quoted in the nurserymen's catalogues, were due to the large blocks of stock taken; but they demonstrate that evergreens can be sold at a much lower price than is now commonly demanded. It will be observed that there is a wide range in the price of stock. The farmer might not find it profitable to use pines at $12.50 per thousand, but if he can buy them at $3 per thousand there is no class of stock that could be so profitably employed in western planting. Even at this rate, however, with the heavy per cent of loss that follows ordinary methods of handling, the stock is expensive by the time the young trees are well established.

As will be observed in the records of work at the several stations, the great difficulty in growing conifers in the plains is in getting them safely through the first year. If seeds are used the tiny plants are in danger of "damping off" before they are three months old; and if young plants are purchased, their first year in their new location is beset with constant difficulties.

The methods of planting in our experiments are detailed in another place and need not be repeated here. But in commending the use of conifers in the treeless region, it is no more than just to point out to the intending planter that no method of treatment that we have yet employed has been successful in a marked degree, although the occasional specimens seen prove that under favorable circumstances success is possible. Underplanting among box elders that are about 10 feet high resulted in a fair admixture of conifers, but the per cent of loss was very heavy (see South Dakota), while underplanting among large Silver Maples, as attempted in Kansas, was a complete failure. The attempt to grow the common evergreens in nursery rows and in screened beds, while not altogether discouraging, was far from satisfactory. In South Dakota, Nebraska, and Kansas no attempt was made to provide for the watering of the trees, and this was probably the principal cause of failure. I have no doubt, with facilities for watering, and provided the young conifers arrive in good condition, they can be grown with but slightly more loss than will result in deciduous trees, particularly in the eastern part of the forestless region. If the farmer can provide a brush screen for his evergreens after getting them into the ground in good shape, and then have the nursery bed near enough to the wind-

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mill pump to admit of flooding it occasionally during dry weather, there would seem to be no reason why the trees would not grow well. The arrival of the stock in good condition, and care in planting to protect the roots from drying and to set the plants firmly at the same depth they stood before is of great importance, for no amount of after care can compensate for neglect in handling.

There are occasional years in the plains when the season is altogether favorable for tree culture—years of unusual rainfall and a consequently plentiful supply of moisture. If such seasons could be foretold no especial difficulty would be experienced in securing a stand of conifers. It was in such a season that the South Dakota planting of 1889 was made, of which details are given on pages 65–7.

In dry years the difficulty of securing a good stand is greatly increased, and it is for this reason that a good water supply will be found of particular value. Having established the young seedlings in nursery, they can be transplanted to their permanent places from time to time, taking advantage of favorable conditions of weather and soil moisture. It will be possible for the farmer to take up the plants with balls of earth attached, and thus more thoroughly protect the roots from exposure than can be done where the trees are received from commercial growers. The method here suggested demands a great deal more labor than is involved in handling the common deciduous trees, but once a stand of evergreens is secured the grove of which they form a part is so much enhanced in value that the additional labor will prove the best possible investment. The evergreens form the ideal wind-break. In the margin of the plantation they carry their branches to the ground, thus turning the strongest winds, while everywhere they present a compact mass of foliage which makes them many times as efficient as broad-leafed trees in breaking the force of winds, especially in winter, when there is the greatest need of protection.

Taking no account of the labor involved, at $3 per thousand, the cost of stock established in the plantation, if only 25 per cent of the trees were saved, would be $12 per thousand. I question if the farmer lives in the treeless region who would not consider his farm increased many times $12 by the presence of a 10-acre grove in which there were 1,000 thrifty evergreens. In point of fact, a 10-acre grove should, at the age of 10 years, contain at least 3,000 evergreens, and with such a stand there is a large margin for expense and loss between the original cost of the conifer stock and the actual value of the plantation.

EXPERIMENTAL PLANTATIONS.

Experimental tree planting in the West first received the attention of the Department in 1891, when an arrangement was made with Mr. Edgar G. Bruner by which he was furnished stock for planting three acres, according to plans furnished, in the Sand Hills of Holt County,

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Nebr. The result of this experiment is recorded in the Report of the Division of Forestry for 1891. Owing to the distance of the Bruner ranch from the railway (25 miles), and the consequent difficulties of inspection, it was thought best to abandon the plantation. It is sufficient here to say that the trees were planted on the crest and higher slopes of a sand ridge which supported a sparse growth of prairie grasses. Three plats were set in different mixtures and by different methods, as follows: In plat 1, only conifers, Jack (Banksian), Scotch, Austrian, Red, and Rock (Bull) Pine, Douglas Spruce, and Arbor Vitæ were used, nearly one-half the trees being Jack (Banksian) Pine. The land was not plowed, but furrows were turned for the trees to be set in, the intervening spaces being left undisturbed, the purpose being to prevent the shifting of the sands. In plat 2, a mixure of conifers and hardwoods, three-fourths of the trees being of the latter type, were set as in plat 1. Plats 3 and 4 were plowed, and the trees were two-thirds conifers and one-third hardwoods.

The plats were examined by the writer in 1894, and the only one which had made a stand was plat 1, which was planted 2 by 2 feet apart, and had received no cultivation; the Jack (Banksian) Pine seemed thoroughly adapted to the locality. The growth, while not large, was healthy and stocky, and the plat made a bright green mass in the brown and dry grasses visible from a distance of several miles. None of the other species had become well established, a few trees only of Red, Rock, and Scotch Pine having grown. In the other three plats scarcely a tree had survived.

The experimental plantings herein described were begun in 1896. The first plantations were located on the farms of the State Agricultural colleges of South Dakota (Brookings), Nebraska (Lincoln), Kansas (Manhattan), and Colorado (Fort Collins). During the year 1896 arrangements were made for establishing stations at the Crookston and Grand Rapids farms of the Minnesota Agricultural College, and at the State Agricultural College of Utah, at Logan. During the present year arrangements have been made for extending the work, the new stations including the agricultural colleges of Texas, at College Station; Oklahoma, at Stillwater, and Montana, at Bozeman.

The basis of these experiments is the following agreement, prepared in the Department of Justice by request of Secretary Morton:

AGREEMENT made this 24th day of November, 1896, by and between the Secretary of Agriculture, hereinafter called "the Secretary," and the Board of Regents of the ——— State Agricultural College, hereinafter called "the College."

I. The College agrees that a parcel or parcels of land of said college, located as may be hereafter agreed upon, and not exceeding twenty-five acres in the whole nor ten acres for the first year, shall be placed under the absolute control of the Secretary to enable him, acting through the appropriate officials of the Department of Agriculture, "to experiment and continue an investigation, and report on the subject of forestry and timbers, for traveling and other necessary expenses in the investigation, and for the collection and distribution of valuable and economic seeds and plants," in accordance with the provisions of an act of Congress of April 25, 1896, entitled

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"An act making appropriations for the Department of Agriculture for the year ending June 30, 1897."

II. The Secretary agrees that he will furnish suitable plans for the planting of trees as well as of all material for planting; that he will direct the care and management of the trees so planted; that such planting and subsequent care and management shall be under the immediate supervision of an officer of the said college or of the Division of Forestry, as the Secretary may determine, said officer to be under the direction of the Chief of the Division of Forestry; and that the labor on said land, being furnished by the said college as it is hereby agreed that it may be, the same shall be paid for by the Department of Agriculture on properly certified accounts in the manner provided for by the rules of said Department.

III. This agreement is to continue in force until terminated by the Secretary, or, if not sooner terminated, until the experimental stage of said forest plantation is past; and upon its termination all improvements upon the land covered by this agreement shall become the property of the College.

——— ———,
Secretary of Agriculture.

THE BOARD OF REGENTS OF THE ——— AGRICULTURAL COLLEGE.

——— ———, *Secretary.*

OBJECTS.

Several lines of inquiry have led to the establishment of these forest-tree planting experiments. Detailed knowledge of successful forest-tree planting is very meager in America, and in the treeless regions, where more planting has been done than within the forest area, successful methods of selection, planting, and treatment are yet to be formulated. Such facts as have been proven by experience stand isolated; no rules of procedure have been determined. Each planter has used such materials as were nearest at hand, and followed methods based not upon a knowledge of trees and their needs, but upon his experience as a farmer.

Thus, the light requirement of species and their judicious mixture have had no place in "tree-claim" planting. The experiments which the Division of Forestry has undertaken have as their objects the determination of the adaptability of our principal economic species to the plains, and successful methods of planting and after treatment that shall be within the range of the average farmer. It is hoped that from these experimental plantings, though they cover but limited areas, results may be gained that will prove practicable in larger operations should opportunity come for undertaking them.

From the passage of the "timber-claim" act of 1872 until now the usual custom in the West has been to plant trees of one species in an entire grove, with wide spaces between the trees. Even when more than one variety has been used the custom has been to plant the several varieties in groups by themselves.

It is proposed in the course of these planting experiments to undertake methods which may, in some instances, be at variance, not only with established practice, but which even give seemingly little promise of success; for it is believed that much may be learned in the way of negative results if the cause of failure is found. The fundamental purpose of these plantings is to secure a sound basis for future practice, and hence a wide latitude will be permitted in planning the experiments.

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BOTANICAL LIST OF TREES USED IN THE PLANTING EXPERIMENTS.

CONIFEROUS SPECIES.

Scientific name.	*Common name.*
1. Pinus strobus.	White Pine.
2. Pinus resinosa.	Red Pine (Norway Pine).
3. Pinus ponderosa var. scropularum.	Rock Pine (Bull Pine).
4. Pinus divericata.	Jack Pine (Banksian Pine).
5. Pinus sylvestris.	Scotch Pine.
6. Pinus austriaca.	Austrian Pine.
7. Larix laricina.	Tamarack (American Larch).
8. Larix europæa.	European Larch.
9. Picea canadensis.	White Spruce.
10. Picea excelsa.	Norway Spruce.
11. Pseudo-tsuga taxifolia.	Douglas Spruce.
12. Abies concolor.	White Fir (Silver Fir).
13. Juniperus virginiana.	Red Juniper (Red Cedar).

BROAD-LEAFED SPECIES.

14. Juglans nigra.	Black Walnut.
15. Populus tremuloides.	Aspen.
16. Populus deltoides.	Cottonwood.
17. Populus certinensis.	Russian Poplar.
18. Betula alba.	European White Birch.
19. Betula lutea.	Yellow Birch.
20. Betula lenta.	Sweet Birch.
21. Ostrya virginiana.	Hop Hornbeam (Ironwood).
22. Castanea dentata.	Chestnut.
23. Quercus alba.	White Oak.
24. Quercus macrocarpa.	Bur Oak.
25. Quercus prinus.	Chestnut Oak.
26. Quercus platanoides.	Swamp White Oak.
27. Quercus rubra.	Red Oak.
28. Ulmus americana.	White Elm.
29. Morus alba tatarica.	Russian Mulberry.
30. Liriodendron tulipifera.	Tulip Tree.
31. Prunus serotina.	Black Cherry.
32. Gleditsia triacanthos.	Honey Locust.
33. Robinia pseudacacia.	Locust (Black Locust).
34. Acer saccharinum.	Silver Maple.
35. Acer negundo.	Boxelder.
36. Fraxinus americana.	White Ash.
37. Fraxinus lanceolata.	Green Ash.
38. Catalpa speciosa.	Hardy Catalpa.
39. Artemisia abrotanum var. tobolskianum.	Artemisia.

NOTE.—The scientific and common names of trees used in this bulletin are those adopted in Forestry Bulletin No. 14, Nomenclature of the Arborescent Flora of the United States.

Following is a list of the plantations made by the Department thus far, with notes on the stand as reported by the several professors of horticulture directly in charge of them. The mixture adopted in

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the several plats is shown by diagram, and a careful study of these diagrams will suggest to the reader a suitable mixture of such species as he may have available for his own planting.

KANSAS.

(Agricultural College Farm, Manhattan.)

At this station the college had already planted about 10 acres in forest plats, a part of which was turned over to the Department for underplanting, together with 6 acres of unplanted land.

UNDERPLANTING.

About 3 acres had been planted to Silver Maples, most of which had begun to fail when the division assumed charge of the work, in the spring of 1896, which gave an opportunity to establish a growth of conifers in the protection of the maples. The grove was planted between twenty and twenty-five years ago, the trees now averaging about 40 feet high. Very few of the trees were in perfect health, but there was a sufficient stand to make an almost continuous shade over the plat. A scattered undergrowth of Hackberry, Gooseberry, Prickly Ash, Dogwood, Elder, Buckberry, native Red Mulberry, Red Elm, White Elm, Catalpa, Chestnut Oak, Red Bud, and Sumach has sprung up among the trees since cultivation was stopped. A slight weed growth and some grasses also occur, making in all considerable soil cover.

The location is on the slope and crest of a slight hill, the crest being the usual high level of the rolling prairie. The soil is the black loam common throughout the West, underlaid with a coarse gravel or broken limestone mixed with clay, below which is stratified limestone. On the crest of the hill the soil is very thin, the land being the poorest on the college farm.

The following trees were planted in the maple grove without disturbing the soil cover: 618 Scotch Pine, 12 to 18 inches high, transplanted; 545 Rock Pine (Bull Pine), 6 to 10 inches high, wild seedlings dug in Rocky Mountains; 1,155 Norway Spruce seedlings, 6 to 10 inches high, nursery grown; 1,235 Douglas Spruce, 6 to 10 inches high, dug in Rocky Mountains, and 257 Bur Oak, 12 to 18 inches high, nursery grown; total, 3,810 trees.

The stock was all in good condition and was planted in with spades. At first there seemed promise of a good stand, Professor Mason reporting 89 per cent of the trees planted alive June 17, but the long hot summer played serious havoc with the young trees, and the report of October 27, at the end of the growing season, showed but 11 per cent of them living. This heavy loss is attributable in part to the too dense shading of the Maples, but it is probable that the great demands of the

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Maples on the soil moisture was the real difficulty. The land was filled with the roots of the older trees, leaving but little opportunity for the conifers to become established.

This experiment having proved a failure, the Maples were again underplanted in the spring of 1897 in the following method (the plat was cleared in strips, as indicated below):

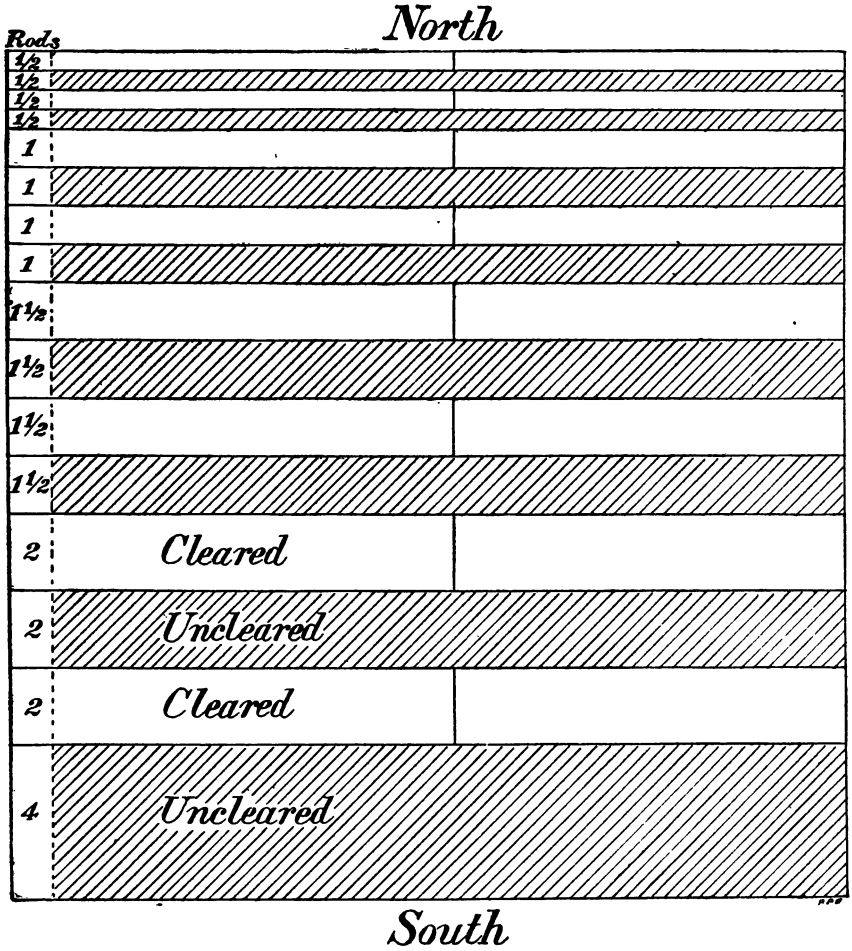

FIG. 1.—Diagram of underplanting in Kansas.

One-half of all the cleared strips was grubbed, plowed deep, and thoroughly cultivated before planting, while from the other the trees only were removed, leaving all undergrowth. In the last half of April the cleared spaces were planted with 1,831 Scotch Pine and 216 Green Ash seedlings, set 4 by 4 feet. Of this planting, 44 per cent was reported living in the plowed land and 52 per cent in the unplowed land on June 30. In October, at the end of the growing season, 99

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Scotch Pine and 93 Green Ash were alive in the plowed portion of the strips, and 143 Scotch Pine and 83 Green Ash in the unplowed portion, a total of 20 per cent of the whole number set in the spring.

PLANTING IN GRASS.

In the spring of 1896 a plat of one-half acre was planted in the unbroken grass land, no preparation whatever having been given the plat. The land is on the crest of the hill and is unfit for cultivation, the soil being a gravelly clay underlaid with limestone. Blue joint (*Andropogon* sp.) and other bunch grasses make a good growth in it. The trees were set as near 4 by 4 feet as possible without marking the land, and the holes were dug without disturbing the grass cover unnecessarily. The ground was so full of stones as to make planting difficult. One thousand two hundred and nine trees were used—915 Scotch Pine and 294 Rock Pine—both in good condition at planting time. On the 17th of June 80 per cent of the Scotch and 97 per cent of the Rock Pine were alive, and on October 27, 1896, 60 per cent of the Scotch and 21 per cent of the Rock Pine survived. In the spring of 1897 the Scotch Pine were replanted, and on June 30 the count resulted in 726 Scotch Pine and 60 Rock Pine. In October, 1897, a count resulted in 673 Scotch and 26 Rock Pine, 58 per cent of the original planting. The trees seemed to be well established, many of the Scotch Pine having grown over 12 inches during the season.

This experiment promises to be a success, since 58 per cent of the number that were originally planted survived the second summer. Compared with either the underplanting noted above, or the field planting which follows, this planting in the unbroken grass lands certainly gives very favorable indications. It should be observed, however, that the grasses in this rocky soil do not form a thick sod, as is the usual condition in the prairies. Professor Mason writes of this plat, under date of June 30, 1897, "Sumach is growing up thick in places, forming a good nurse crop for the pines (Scotch). In fact, they are making a better growth here than in any other plat. Some have grown 18 to 20 inches this season. The Rock Pine were not replanted in this plat, and the last year's trees do not seem to be growing well." It has been observed at other stations that wild plants of the Rock Pine (*Pinus ponderosa scopulorum*) are difficult to establish and of slow growth the first few years.

FIELD PLANTING.

In April, 1896, a plat of 1.11 acres, occupying the crest of a ridge, soil very thin, clay loam mixed with gravel, with gravel subsoil on limestone, was planted to the following species: 99 Bur Oak, 99 Ironwood, 391 Bird Cherry, 607 Douglas Spruce, 499 Norway Spruce, 697 Rock Pine, 782 Scotch Pine, and 3,128 Jack (Banksian) Pine. The

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Ironwood and Bird Cherry were in bad condition, having gone astray in transit; the Jack Pine were wild seedlings, dug in the Minnesota pineries; the Rock Pine and Douglas Spruce were wild Rocky Mountain seedlings, dug in Pueblo County, Colo., and the remaining trees were nursery stock. All were carefully planted with spades.

On June 17 the conifers were reported a good stand, being 72 per cent of the number planted. October 28 Professor Mason reported 38 per cent of those planted alive—Jack Pine and White Spruce having made a stand of 56 and 54 per cent, respectively.

In April, 1897, the blanks in this plat were planted with Artemisia, Tulip Tree, Norway Spruce, and Scotch Pine, and on June 30 the plat contained the following trees: 1,225 Artemisia, 655 Scotch Pine, 43 Rock Pine, 1,580 Jack Pine, 467 Norway Spruce, 165 Tulip, 3 Oak, 50 Douglas Spruce; total, 4,188. In October, 1897, a count of this plat resulted: 1,175 Artemisia, 620 Scotch Pine, 7 Rock Pine, 1,418 Jack Pine, 293 Norway Spruce, 117 Tulip, 2 Oak, 50 Douglas Spruce, the total being 58 per cent of the original number planted.

It will be observed that in this plat, which has received thorough cultivation since it was planted, the Scotch and Rock Pines have not made as good a stand as in the grass plat above noted. It may be that in this stony soil the protection afforded by the tall bunch grasses is more beneficial than cultivation, the grasses not forming a compact sod. The conditions noted are common on the bluffs along the Kansas rivers, but it is believed that the location is in no sense typical of the prairies away from the rivers, nor of the plains in the western part of the State. Regarding the trees set last spring (1897) in this plat Professor Mason says: "The Scotch Pines were reset partly from nursery stock received this spring, and partly with trees that had grown for a year in nursery rows here. Of the latter scarcely any died."

PLATS PLANTED IN 1897.

Four plats of somewhat less than 1 acre each were planted in 1897. These were all designed with light-foliaged trees as nurses, and in all of them spaces have been left for the conifers, which will be planted in hereafter, as indicated in the plans. These plats are on high prairie, the soil somewhat deeper than in the plats above noted and quite free from stones, underlaid with limestone. The land was formerly occupied by an orchard, which had been cut out three years previously and the field planted to small grain, followed by corn. In the fall of 1895 it was plowed 10 to 12 inches deep, and was in fine condition when planted in April, 1897.

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PLAT A.—*3 by 3 feet, 4,840 trees per acre.*

O A S A P A E A O

A A A A A A A A A

S A P A E A S A P

A A A A A A A A A

P A E A S A P A E

A A A A A A A A A

E A S A P A E A S

A A A A A A A A A

O A P A E A S A O

A—Artemisia	3,630
E—White Elm	378
O—Bur Oak	75
P—Scotch Pine	379
S—White Spruce	378

The Artemisia, although having very fine foliage, branches freely from the crown, and makes a much denser shade than was supposed it would, from descriptions received when the cuttings were ordered. It is much the most vigorous grower of any plant included in these experiments, making frequently a stem 42 inches long from the cutting the first year and spreading 4 to 6 feet. It can not therefore be used in such dense planting, but has an advantage in covering so much ground at once. The Elm and Spruce are more shade enduring than the Pine, and have been so arranged as to form two-thirds of the plat after the nurses have been removed. In case Artemisia threatens to shade out the slower-growing forms, it will be cut back sufficiently to protect the others. The Scotch Pines were set in at the same time as the others, transplanted trees 10 to 15 inches high being used. Spaces for the White Spruce were left, and this species will be planted in next spring, so as to have the protection of one year's growth of the remaining species.

On June 30 a count of the living trees in the plat resulted as follows: 2,355 Artemisia, 19 Oak, 40 Sweet Gum (set by mistake in place of Oak), 279 Elm, 190 Scotch Pine, the total being 68 per cent of the number planted. Dry weather immediately following the planting was the cause of the poor stand. In October, at the end of the growing season, a count of the plat resulted as follows: 2,417 Artemisia, 163 Scotch Pine, 55 Oak and Gum, 246 White Elm, or 62 per cent of the number planted.

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PLAT B.—*3 by 3 feet, 4,840 trees per acre.*

D P A P B P A P R P A P D P

P P P P P P P P P P P P P P

O P B P A P R P A P D P O P

P P P P P P P P P P P P P P

B P A P R P A P D P A P B P

P P P P P P P P P P P P P P

A P R P A P D P A P B P A P

P P P P P P P P P P P P P P

R P A P D P A P B P A P R P

P P P P P P P P P P P P P P

O P D P A P B P A P R P O P

P P P P P P P P P P P P P P

P—Aspen	3,630
O—Oak (24 by 36)	50
A—American Larch	555
B—Rock Pine	202
R—Red Cedar	202
D—Douglas Spruce	201

The Aspen were one year seedlings, dug in the woods near Sturgeon Bay, Wis., and were slightly mixed with Cottonwood. The Oaks were nursery grown, 10 to 15 inches. The Larch were nursery-grown seedlings 10 to 12 inches; they had started growth in transit, and were therefore not in good condition at planting time. Spaces were left for the remaining conifers. It will be observed that three-fourths of the mixture are Aspen—light foliaged, light-demanding trees. Of the remainder, over one-half are also of light-demanding species, the only shade-enduring forms being Red Cedar and Douglas Spruce. This plat is designed to illustrate the effects of planting a great excess of light-demanding species together as nurses for evergreens, which are supposed to require the protection of other trees during their infancy.

On June 30 the living trees were 2,752 Aspen (and Cottonwood), 260 Larch, 33 Oak, or 74 per cent of the trees set. In October the living trees numbered 2,367 Aspen, 5 Larch, and 24 Oak, or 56 per cent of the original planting. It is hardly to be supposed that the American Larch, a tree of the northern swamps, will be useful so far south and under

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conditions so different from its habitat. The species was planted at the Kansas, Nebraska, South Dakota, and Crookston, Minn., stations to get an indication of its possible cultural range in the plains.

PLAT C.—*3 by 3 feet, 4,840 trees per acre.*

B P P B B P P B

P D B A P D B A

B B P P B B P P

P F B C P F B C

B P P B B P P B

P D B A P D B A

B B P P B B P P

P O B C P F B C

B P P B B P P B

P D B A P D B A

B—Birch (Yellow and Sweet mixed)	1,815
P—Aspen (and Cottonwood)	1,815
O—Oak (24 by 36 feet)	50
F—Green Ash	252
C—Hardy Catalpa	302
A—Austrian Pine	303
D—Douglas Spruce	303

The Birch and Aspen were one-year seedlings from the woods at Sturgeon Bay, Wis. The Catalpa and Ash were one-year seedlings nursery grown. The Oaks were 12 to 15 inch nursery-grown transplants. Spaces were left for the Pines and Spruces to be set in the following year. The plat is designed to test Aspen and Birch, light-demanding trees, as nurses for the others, which are so arranged that the light-demanding Pine and Ash shall alternate with the shade-enduring Spruce and Catalpa.

On June 30 there were living 1,435 Aspen and Cottonwood, 850 Birch, 244 Catalpa, 237 Green Ash, 40 Oak, or 69 per cent of the trees set. The count of October resulted: 1,268 Aspen, 710 Birch, 247 Catalpa, 237 Ash, 40 Oak, or 61 per cent of the number planted.

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PLAT D.—*3 by 3 feet, 4,840 trees per acre.*

P E P B P E P B

B R B C B R B C

B A B A B A B A

B Pi B L B Pi B L

P B P S P B P S

B R B C B R B C

B A B A B A B A

B Pi B L B Pi B L

P E P B P E P B

P—Aspen	605
B—Birch	2,117
A—Artemisia	605
E—White Elm	151
S—Catalpa	151
R—Red Cedar	303
Pi—Rock Pine	303
L—American Larch	303
C—White Fir	302

In the above scheme, in the third row from the top, reading across the page, and in corresponding rows throughout, A and B should change places, but the plat was planted as indicated in the scheme.

In this plat the principal nurse tree is Birch, so arranged that part of the Birch can be retained as permanent trees. Blank spaces were left for the Red Cedar, Rock Pine, and Silver Fir.

On June 30 there were living 468 Aspen, 1,153 Birch, 85 American Larch, 125 Catalpa, 355 Artemisia, 100 Elm, or 61 per cent of the total number planted. In October the plat contained 830 Birch, 395 Aspen, 346 Artemisia, 82 White Elm, 8 Larch, 122 Catalpa, or 47 per cent of the total number planted.

NOTES ON THE KANSAS PLATS.

In the plats planted in the spring of 1897, light-demanding species viz, Aspen, Birch, and Artemisia, have formed three-fourths of each plat. The Aspen is a light-foliaged tree which does not make a dense shade, and is short lived. It is believed that it will afford the requisite protection for Pines, Spruces, Firs, and Cedars, until they become established. With the exception of a few Oaks, all the permanent trees in Plat C (that is, permanent as compared with the nurse trees, which are only intended to stand about ten years) are conifers. In the

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remaining plats hardwoods and conifers are mixed. In all the plats it will be noted that each permanent tree is entirely surrounded by nurses. When the nurses are removed, the plat will show an alternation of comparatively light-demanding with shade-enduring kinds.

It must be understood that the shade endurance of different species is relative. For instance, in Plat A, the trees aside from Artemisia stand as indicated in the accompanying diagram:

O S P E

S P E S

P E S P

E S P E

S P E S

Oak and Pine require most light, Elm less than these, and Spruce least of the four; and the two light-demanding species are separated by the more shade-enduring forms.

It is well to introduce a few slow-maturing species, such as Oak, Black Walnut, Hickory, etc., in plantings where the soil is adapted to them, and by placing them at wide intervals the general development of the grove will not be affected by their slower growth. While it is true that the Black Walnut is a rapid-growing tree, it does not attain its full value until very old, as compared with Elm, Catalpa, Locust, etc.

Measurements of growth.

The following measurements of the growth of trees set in 1896 and 1897 will give a general idea of the action of the species named under the conditions prevailing at the Kansas station. The measurements of trees planted in 1896 give the total growth for two years, while those for 1897 give the length of new wood made in that year only—only the leading branch being measured. The measurements were taken July 15, 1897:

Growth for 1896 and 1897.

Species of tree planted.	Longest.	Average.
Trees set spring of 1896.	*Inches.*	*Inches.*
Scotch Pine	20	9.3
Rock Pine	7	5.2
Jack Pine	18	10.5
Norway Spruce	10	5
Douglas Spruce	7	4.1
Artemisia	60.5	51
Tulip tree	24	14.6
Bur Oak	10	9.8
Ironwood	10	8.5
Scotch Pine (set in grass plat)	28	16.5
Rock Pine (set in grass plat)	4	2.1

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Growth for 1896 and 1897—Continued.

Species of tree planted.	Longest.	Average.
Trees set spring of 1897.	*Inches.*	*Inches.*
Scotch Pine	6.5	3.8
Red Cedar (in nursery rows)	5.5	4.1
Larch	4.5	2.6
Catalpa	24	14.5
Green Ash	10	6.8
Birch	10	6.6
Elm	22	12
Artemisia	57	38.1
Oak (mxt. black species)	31	11.3
Populus (Blk. B)	47.5	21
Populus (Blks. C. & D.)	25	13.8

NEBRASKA.

For the planting experiments at the State University experiment station a field was set apart on the east side of the university farm, adjoining a 15-acre grove of pure-planted Cottonwood. The land slopes to the east and north and the soil is the typical prairie of the eastern part of Nebraska, a black loam, underlaid to an unknown depth with a rather stiff yellow clay. The fact that the Cottonwood, which occupy the low land adjoining the forest plats, has made a splendid growth (averaging 60 feet in height at 25 years of age), and form one of the best pure-planted groves of this species I have ever seen, indicates that the subsoil is sufficiently porous to permit perfect root development, while the remarkable growths herein recorded indicate generally favorable conditions, at least during the past two years.

The field is divided into 1-acre plats, ten of which have been planted thus far. In 1896 five plats were planted, the nurse trees being all of shade-enduring species. In 1897 five acres were planted, in which the nurse trees were all of light-demanding species. In the 1896 plantings all the trees were set, while in the 1897 plantings blank spaces were left for the conifers, which will be filled the coming year or later. It is hoped that the two sets of plats, planted on such opposing bases, will demonstrate the advantages and disadvantages of both. The plantings of 1897 had for their especial purpose the creation of conditions favorable to evergreens, and must be considered from this point of view.

PLANTINGS OF 1896.

Soil preparation.—The land for plats 1 to 5 was ordered plowed 12 inches deep, but owing to the excessive dry weather of the previous year this was impossible. The plowing averaged about 6 inches deep, being very irregular. The plats were thoroughly harrowed in the spring and were in perfect condition, aside from the shallow plowing, at planting time. The soil was fresh when planting began, having had a good rain

a few days before. There was no rain after April 15 until April 28, when 1.2 inches fell. The conifers were planted between showers following this heavy rain.

Condition of stock.—All the stock, except as indicated, was nursery grown. The European Larch were leafed out fully one-fourth when planted. The Cherry buds were showing green, the Elm buds were much swollen; all other stock dormant and in good condition, except the Birch and Black Locust, neither of which started well. The age and size of stock was as follows:

Russian Mulberry, Silver Maple, Honey Locust, Hardy Catalpa, Black Cherry, Black Locust, and Tulip, one year, 10 to 18 inches. White Elm, Green Ash, White Ash, one year, 6 to 10 inches. Sweet Birch (poor). Canoe Birch, Bur Oak, 12 to 18 inches. Rock (Bull) Pine, Douglas Spruce, wild seedlings, 6 to 10 inches, dug in mountains, Beulah, Colo. Jack Pine, wild seedlings, 8 to 12 inches, dug in woods, Carlton, Minn., Scotch Pine, nursery grown, transplanted, 12 to 15 inches.

Date of planting.—Planting began April 15 and was continued to April 20, when all the trees except Jack and Rock Pine and Douglas Spruce were set. These were planted April 28 and 29.

PLAT 1.—*2 by 3 feet, 7,260 trees.*

S	A	D	A	S	A	D	A
M	B	M	B	M	B	M	B
C	E	L	E	C	E	L	E
M	B	M	B	M	B	M	B
D	A	S	A	D	A	S	A
M	B	M	B	M	B	M	B
L	E	C	E	L	E	C	E
M	B	M	B	M	B	M	B
S	A	D	A	S	A	D	A

M—Russian Mulberry	1,815
B—Jack Pine	1,815
D—Douglas Spruce	454
S—Scotch Pine	454
A—Silver Maple	907
E—European Larch	908
L—Honey Locust	454
C—Hardy Catalpa	453

Two hundred and forty-three Artemisia cuttings were substituted in nine rows for Jack Pine.

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Professor Card (Horticulturist, Nebraska University Experiment Station), May 30, 1896: "30 per cent of pines and 40 per cent of larches failed; others a fair stand." June 12, 1896, result of count of living trees: 1,772 Russian Mulberry (98 per cent), 992 Jack Pine (63 per cent), 162 Artemisia, 413 Douglas Spruce (91 per cent), 298 Scotch Pine (63 per cent), 872 Silver Maple (96 per cent), 642 European Larch (71 per cent), 126 Honey Locust (28 per cent), 41 Tulip (substituted for Honey Locust), and 405 Catalpa (89 per cent).

October 1, 1896, result of count: 1,779 Russian Mulberry, 833 Jack Pine, 145 Artemisia, 847 Silver Maple, 398 Catalpa, 151 Honey Locust (and Tulip substituted), 296 Scotch Pine, 392 European Larch, 233 Douglas Spruce; or 70 per cent of planting.

April 15, 1897 (count of conifers only): 287 Scotch Pine, 756 Jack Pine, 206 Douglas Spruce, 289 European Larch.

The blanks in Silver Maple, Catalpa, Scotch Pine, Jack Pine, and European Larch were replanted in the spring of 1897.

June 30, 1897, result of count: 1,800 Russian Mulberry, 898 Silver Maple, 428 Catalpa, 193 Honey Locust (and Tulip substituted), 318 Scotch Pine, 131 Douglas Spruce, 1,004 Jack Pine, 146 Artemisia and 154 European Larch; or 67 per cent of the original number planted.

In July this plat had grown so dense as to render further cultivation impossible, and Dr. B. E. Fernow, on inspecting it at this time, gave orders to head in the Mulberries and Maples to prevent their shading the conifers too much. The frontispiece is a picture of this plat taken in full leaf.

Count reported October 12, 1897: 1,560 Russian Mulberry, 590 Silver Maple, 378 Catalpa, 50 Tulip, 221 Scotch Pine, 155 Douglas Spruce, 820 Jack Pine, 317 European Larch; or 56 per cent of the original number living. Discrepancies in the counts will be observed. No Honey Locust is reported in this count, and more Larch than were noted in the last count. Inaccuracies may be due to carelessness on the part of the employee to whom the work was intrusted.

Whether such close planting is advisable is yet to be demonstrated. The principal factors to be considered are (1) cost of stock; (2) cost of cultivation; (3) will crowding be too great, necessitating more labor in thinning, or protecting the permanent trees, than would have been required for cultivation at wider intervals, say 4 by 4 feet? (4) will the comparatively limited amount of soil moisture sustain such an intricate root system as will result from the thrifty early growth of so many trees?

The questions of cost of stock and cultivation are so entirely local that each planter must determine them for himself. If he can gather his own seed from near-by native trees, and grow his seedlings one year, the cost of stock is reduced to a minimum and becomes practically nothing. Of course additional labor in planting, at a season of

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the greatest activity on the farm, must be considered also. The effect of close planting on the trees and on the soil can be determined only by several years of observation. There can be little doubt that the many days of bright sunshine and the almost constant winds will affect tree growth very differently from what would be observed in the Eastern States.

PLAT 2.—*3 by 3 feet, 4,840 trees.*

B	M	B	M	B	M	B	M	B	M
M	O	M	D	M	P	M	D	M	O
B	M	B	M	B	M	B	M	B	M
M	D	M	C	M	D	M	C	M	D
B	M	B	M	B	M	B	M	B	M
M	P	M	D	M	P	M	D	M	P
B	M	B	M	B	M	B	M	B	M
M	D	M	C	M	D	M	C	M	D
B	M	B	M	B	M	B	M	B	M
M	O	M	D	M	P	M	D	M	O

M—Russian Mulberry	2,420
B—Boxelder	1,210
C—Black Cherry	303
O—Bur Oak	75
P—Rock Pine	227
D—Douglas Spruce	605

In this plat (Plate II) Boxelder and Russian Mulberry, the nurse trees, make up three-fourths of the trees. Of the remainder, three-fourths again (Douglas Spruce and Black Cherry) are shade enduring to a greater degree than the Pines and Oaks. Should the Rocky Mountain conifers become established and prove adapted to the prairies, this mixture will prove an excellent one.

Reports.

June 30, 1896, result of count: 2,251 Russian Mulberry, 934 Boxelder, 158 Artemisia (substituted for Boxelder), 276 Douglas Spruce, 96 Rock Pine, 295 Black Cherry, and 68 Bur Oak; or 84 per cent of total.

October 1, 1896, result of count: 2,387 Russian Mulberry, 935 Boxelder, 134 Artemisia, 23 Rock Pine, 348 Douglas Spruce, 280 Black Cherry, 43 Bur Oak; or 88 per cent. (A discrepancy will be noted in these two counts, probably owing to greater care in the latter.)

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April 15, 1897, count (of conifers only): 304 Douglas Spruce, 9 Rock Pine. The Spruce and Oak were replanted in the spring of 1897.

June 30, 1897, result of count: 2,377 Russian Mulberry, 948 Boxelder, 269 Black Cherry, 64 Bur Oak, 120 Douglas Spruce, 10 Rock Pine; or 78 per cent of original planting.

Count of October 12, 1897: 1,632 Russian Mulberry, 903 Boxelder, 100 Black Cherry, 45 Bur Oak, 209 Douglas Spruce, 117 Rock Pine; or 62 per cent of original planting. Compared with the count of June 30, it is evident that errors have been made.

PLAT 3.—*3 by 4 feet, 3,630 trees.*

M L M L M L M L M

C M A M Y M E M C

M L M L M L M L M

A M Y M E M C M A

M L M L M L M L M

Y M E M C M A M Y

M L M L M L M L M

E M C M A M Y M E

M L M L M L M L M

C M A M Y M E M C

M—Russian Mulberry	1,815
E—European Larch	907
C—Black Cherry	227
Y—Yellow Birch	227
A—Green Ash	227
L—White Elm	227

In this plat no evergreens are used. European Larch, a slender, erect tree, is used with Russian Mulberry as a nurse, and the Larch should stand until of good post size. It is probable that the remaining species would have been better disposed had the Elm come between the Birch and Ash.

Reports.

June 12, 1896, result of count: 1,803 Russian Mulberry, 573 Larch, 114 Black Cherry, 100 Yellow Birch, 207 Green Ash, and 207 White Elm, or 85 per cent.

October 1, 1896, result of count: 1,803 Mulberry, 395 Larch, 200 Cherry, 51 Birch, 205 Ash, and 207 Elm. (First count of Cherry probably an error.) Birch, Ash, Elm, and Larch were replanted in the spring of 1897.

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June 29, 1897, result of count: 1,820 Mulberry, 207 Cherry, 198 Ash, 215 Elm, 76 Birch, 215 Larch, or 75 per cent of original planting.

October 12, 1897, result of count: 1,246 Mulberry, 55 Cherry, 150 Ash, 55 Birch, 306 Larch; no report was made of Elm, and the count is evidently incorrect.

PLAT 4.—*2 by 4 feet, 5,445 trees.*

A	C	Ch	L	E	C	Y	L	A
B	M	B	M	B	M	B	M	B
Ar	C	Ar	C	Ar	C	Ar	C	Ar
M	B	M	B	M	B	M	B	M
E	L	Y	C	A	L	Ch	C	E
B	M	B	M	B	M	B	M	B
L	Ar	L	Ar	L	Ar	L	Ar	L
M	B	M	B	M	B	M	B	M
A	C	Ch	L	E	C	Y	L	A

A—White Ash	171
E—White Elm	171
Ch—Black Cherry	170
Y—Yellow Birch	171
C—Catalpa	680
L—Black Locust	680
M—Silver Maple	1,361
B—Boxelder	1,361
Ar—Artemisia	680

In this plat an attempt was made to plant trees of useful timber at distances of 4 by 4 feet, filling in with less valuable species as nurses—Silver Maple, Boxelder, and Artemisia. Of what may be called the permanent trees (those set 4 by 4 feet) two-thirds are of Catalpa and Black Locust, species especially valuable for post timbers, and which could be cut out for this purpose when from 10 to 20 years of age, leaving the Elms, Birch, Cherry, and Ash at 8 feet apart to reach a larger size. Of these four species, the light-demanding Ash and Birch are alternated with the more shade-enduring Elm and Cherry.

Reports.

June 12, 1896, result of count: 159 Black Cherry, 1,271 Boxelder, 1,227 Silver Maple, 313 Artemisia, 580 Catalpa, 175 White Ash, 165 White Elm, 43 Yellow Birch, and 62 Black Locust.

October 1, 1896, result of count: 145 Cherry, 1,263 Boxelder, 1,201

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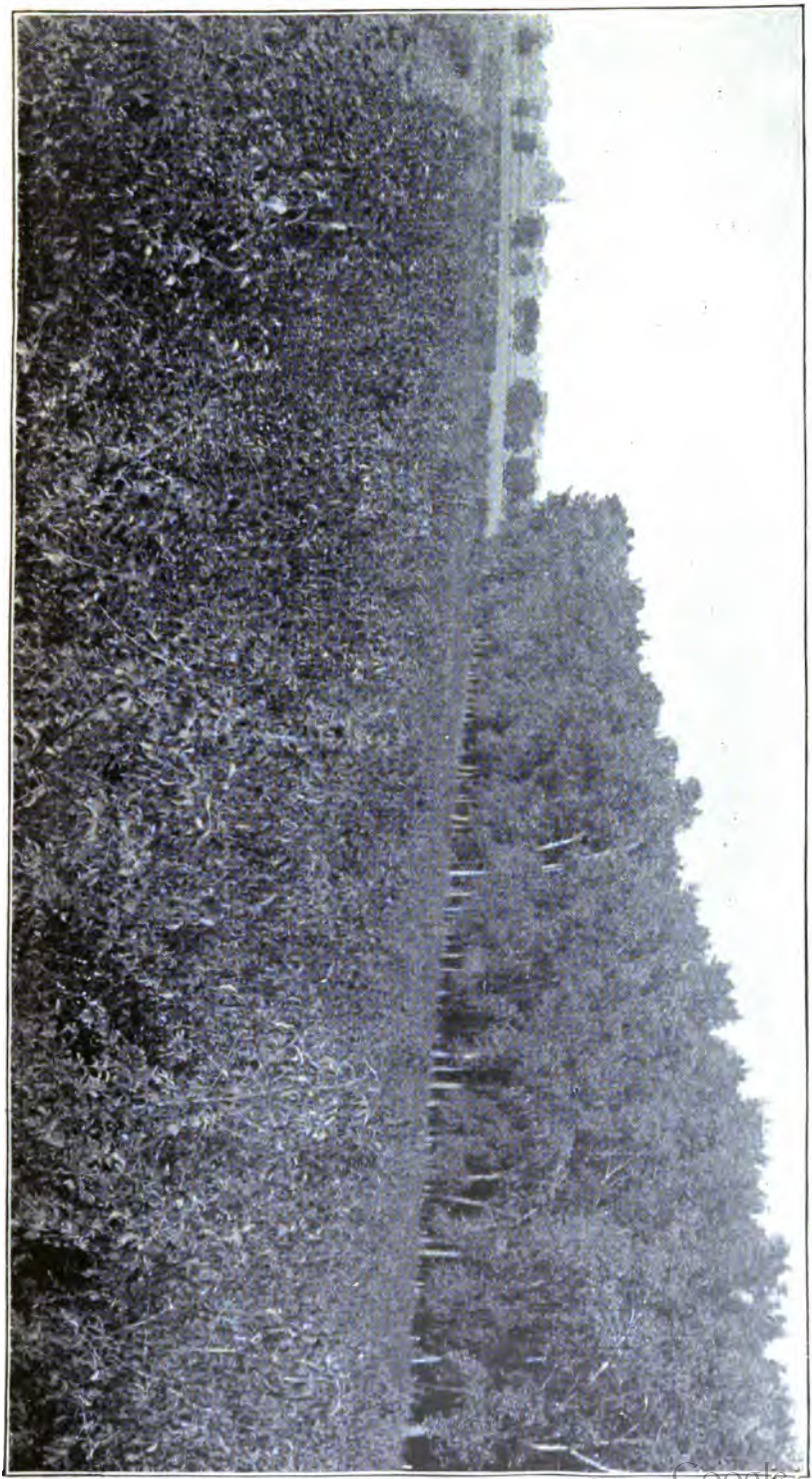

NEBRASKA PLANTATION—PLAT 2.

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Maple, 308 Artemisia, 637 Catalpa, 161 Ash, 161 Elm, 26 Birch, and 62 Black Locust.

Blanks in Artemisia were reset in the spring of 1897.

June 29, 1897, result of count: 150 Cherry, 1,240 Boxelder, 1,185 Maple, 736 Artemisia, 568 Catalpa, 165 Ash, 165 Elm, 24 Birch, and 134 Black Locust.

October 12, 1897, result of count: 114 Cherry, 1,254 Boxelder, 1,165 Maple, 840 Artemisia, 660 Catalpa, 70 Ash; other species not reported.

PLAT 5.—*4 by 4 feet, 2,722 trees.*

O E C A O E C

M L Ma L M L M

D A P E D A P

M L Ma L M L M

O E C A O E C

M L Ma L M L M

D A P E D A P

M L Ma L M L M

O—Bur Oak	171
E—White Elm	340
A— { White Ash / Green Ash }	340
C—Black Cherry	170
Ma—Silver Maple	340
L—European Larch	680
D—Douglas Spruce	170
M—Jack Pine	340
P—Rock Pine	171

Tulip, Birch, and Artemisia were substituted in small quantities for Elm, Ash, Larch, and Maple.

This plat occupied the highest land in the plantation. The reports have not been satisfactory, as some of the species which are not mentioned in the first report are noted later.

Reports.

June 12, 1896, result of count: 166 Oak, 337 Larch, 22 Birch, 95 Pine, 308 Elm, and 332 Ash.

October 1, 1896, result of count: 315 Silver Maple, 93 Oak, 246 Larch, 12 Pine, 96 Douglas Spruce, 171 Cherry, 272 Elm, 332 Ash.

In the spring the blanks in Silver Maple, Elm, Oak, and Larch were reset with Maple, Artemisia, Tulip, and Larch.

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June 29, 1897, result of count: 631 Silver Maple, 206 Artemisia, 331 Ash, 204 Elm, 40 Tulip, 174 Cherry, 18 Birch, 476 Larch, 35 Douglas Spruce, 18 Pine; or 78 per cent of original number planted.

October 12, 1897, result of count: 250 Silver Maple, 340 Artemisia, 200 Ash, 100 Elm, 150 Cherry, 310 Larch; remaining species not reported.

PLANTINGS OF 1897.

In these plats light-demanding trees are used as nurses, among which a few Oaks and Black Walnuts were set and blanks left for conifers to be planted in hereafter. Cuttings of Artemisia were used. Aspen and Birch were wild seedlings, dug in the woods at Sturgeon Bay, Wis. The Aspen are slightly mixed with Cottonwood. Larch are nursery-grown seedlings, 10 to 15 inches high; growth had started in transit, leaving the stock in poor condition at planting time. Walnut, 1-year-old seedlings, grown in nursery.

PLAT 6.—*3 by 3 feet, 4,840 trees.*

A A A A A A A A

A S A L A S A L

A A A A A A A A

A W A S A P A S

A A A A A A A A

A S A L A S A L

A A A A A A A A

A P A S A P A S

A A A A A A A A

A—Artemisia	3,630
P—Rock Pine (*a*)	227
S—White Spruce (*a*)	605
L—American Larch	303
W—Black Walnut (24 by 24 feet)	75

a To be planted in 1898 or later.

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June 30, 1897, result of count: 2,466 Artemisia, 182 Larch, 75 Walnut; or 68 per cent.

October 12, 1897, result of count: 2,850 Artemisia, 23 Larch, 70 Walnut; or 73 per cent of number planted.

From the action of Artemisia in other places it is probable that its rapid growth will prevent its use as a nurse tree; should the conifers become established, however, they should be able to overcome the Artemisia, which is a tall-growing shrub, thus saving the cost of any thinning whatever. Among the conifers it will be noticed that the light-demanding kinds, Larch and Pine (and the Oaks also), are each surrounded by the shade-enduring Spruces.

PLAT 7.—*3 by 3 feet, 4,840 trees.*

P O P D P S P D P W

P P P P P P P P P P

P D P R P D P R P D

P P P P P P P P P P

P S P D P S P D P S

P P P P P P P P P P

P D P R P D P R P D

P P P P P P P P P P

P W P D P S P D P O

P—Aspen	3,630
D—Douglas Spruce (*a*)	605
R—Red Cedar (*a*)	303
S—Scotch Pine (*a*)	227
O—Oak { Chestnut Oak / Swamp White Oak }	37
W—Black Walnut	38

a To be planted hereafter.

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June 30, 1897, result of count: 3,050 Aspen, 15 Oak, 18 Walnut; or 83 per cent.

October 12, 1897, result of count: 2,845 Aspen, 60 Oak and Walnut; or 78 per cent.

Of the permanent trees in this plat (the Aspen being designed as nurses), three-fourths are shade enduring (Douglas Spruce and Red Cedar), and the remainder are light demanding.

PLAT 8.—*3 by 3 feet, 4,840 trees.*

W	B	C	B	P	B	C	B	W
B	B	B	B	B	B	B	B	B
S	B	P	B	S	B	A	B	S
B	B	B	B	B	B	B	B	B
P	B	C	B	A	B	C	B	P
B	B	B	B	B	B	B	B	B
S	B	A	B	S	B	P	B	S
B	B	B	B	B	B	B	B	B
W	B	C	B	P	B	C	B	W

B—Yellow Birch	3,630
W—Black Walnut	75
A—White Fir (*a*)	227
P—Austrian Pine (*a*)	303
S—White Spruce (*a*)	302
C—Red Cedar (*a*)	303

In this plat Yellow Birch, probably mixed with Sweet Birch, is used as the nurse tree, and of the remaining species, all of which are now being grown in nursery at the station, to be set into the plat when well rooted, the Spruce, Fir, and Cedar are shade enduring and the Pine is light demanding.

a To be planted hereafter.

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June 30, 1897, result of count: 2,814 Birch, 74 Walnut, or 78 per cent. October 12, 1897, result of count: 2,900 Birch, 70 Walnut, or 80 per cent. Evidently an error in one of the counts.

PLAT 9.—*3 by 3 feet, 4,840 trees.*

B	B	P	P	B	B	P	P	B	B
P	S	B	X	P	D	B	Y	P	S
B	P	P	B	B	P	P	B	B	P
P	X	B	D	P	Y	B	S	P	X
B	B	P	P	B	B	P	P	B	B
P	D	B	Y	P	S	B	X	P	D
B	P	P	B	B	P	P	B	B	P
P	Y	B	S	P	X	B	D	P	Y
B	B	P	P	B	B	P	P	B	B
P	S	B	X	P	D	B	Y	P	S

B—Birch	1,815
P—Aspen	1,815
X—Rock Pine (*a*)	302
Y—Scotch Pine (*a*)	302
D—Douglas Spruce (*a*)	303
S—White Spruce (*a*)	303

In this plat Birch and Aspen are used as nurses, so arranged that each permanent tree is bordered on one side (diagonal) by Birch and on the other by Aspen. Of the permanent trees the Pines are light-demanding and the Spruces shade enduring.

a To be planted hereafter.

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Reports.

June 30, 1897, result of count: 1,721 Aspen, 1,584 Birch, or 91 per cent.

October 12, 1897, result of count: 1,600 Aspen, 1,550 Birch, or 87 per cent.

PLAT 10.—*3 by 3 feet, 4,840 trees.*

P D P D P D

L B L B L B

P W P W P W

L B L B L B

P D P D P D

L B L B L B

P W P W P W

L B L B L B

P—Aspen	1,210
B—Birch	1,210
L—American Larch	1,210
D—Douglas Spruce (*a*)	605
W—White Spruce (*a*)	605

In this plat Aspen, Birch, and Larch are designed as the nurse trees for two shade-enduring species. It is not known whether Douglas or White Spruce is the more shade enduring, and blanks in these kinds may be filled with pines or hard woods in the future, or a portion of the Birches may be left standing.

Reports.

June 30, 1897, result of count: 919 Birch, 772 Aspen, and 820 Larch, or 69 per cent.

October 12, 1897, result of count: 1,025 Birch, 950 Aspen, 200 Larch. Evidently an error in count of Birch and Aspen in one or both counts.

NOTES ON NEBRASKA PLANTINGS.

Measurement of growth.—The following measurements were made July 29, 1897, and include the total height of trees measured. The Catalpas, Black Locusts, and Mulberries in almost all cases sprouted from the root, and the remaining trees were, with but few exceptions, not over 12 inches high when planted, the tallest at planting being the Oaks. The average growth was determined by measuring every tree of the variety as it came in the plat up to the number of 25, and taking the average of such measurements.

a To be set in hereafter.

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Planted 1896.

Name.	Height when planted.	Greatest height.	Average height.
	Inches.	*Inches.*	*Inches.*
Black Locust	10–15	104	76½
Hardy Catalpa	10–15	88	56
Artemisia (cuttings)	.....	68	52
Black Cherry	12–18	67	51½
Boxelder	10–15	66	47
Silver Maple	10–15	61	48
Tulip	10–15	53	27½
White Elm	8–12	47	38½
Green Ash	8–12	46	37
Russian Mulberry	8–12	46	35½
Yellow Birch	10–18	46	34
White Ash	8–12	44	35½
Honey Locust	8–12	40	29
Bur Oak	12–24	39	30½
European Larch	8–12	26	21½
Jack Pine	8–12	24	19
Scotch Pine	8–15	20	17
Douglas Spruce	8–10	17	13½
Rock (Bull) Pine	8–10	14	10½

Planted 1897.

Name.	Height when planted.	Greatest height.	Average height.
	Inches.	*Inches.*	*Inches.*
Artemisia (cuttings)	.....	40	34
Birch	10–18	28	21½
Black Walnut	8–12	25	19
Aspen	10–18	24	20½
Silver Maple	10–15	23	19
American Larch	8–12	9	7½

Cultivation.—In 1896 the plats were cultivated five or six times, and in 1897 one man devoted his entire time to the care of the 10-acre plats and the conifer nursery and seed beds. A successful effort was made to keep the plats clear of weeds and the soil in fine tilth throughout the growing season.

Close or wide planting.—The plantings of 1896 were made at varying distances to watch the effect on growth. Heretofore 4 by 4 feet has been considered close planting in the West, a more common method being to plant from 2 to 3 feet apart in rows 8 to 12 feet apart. It was thought that the closer planting might result in a more thorough windbreak, and in lessening the amount of cultivation.

In plat 1, planted 2 by 3 feet, one cultivation was given the second year from planting, and the nurse trees were cut back at the instance of Mr. Fernow, who found that they were crowding the permanent trees too much when he inspected the plantation July 15.

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The illustrations made from photographs of plats (see frontispiece and page 51) taken at midsummer show how completely the ground was shaded in the second year, in plantings 2 by 3 and 3 by 3 feet.

COLORADO.

The State Agricultural College of Colorado is located at Logan, about 70 miles north of Denver, and 5 miles east of the foothills of the Rocky Mountains. The college farm is a slightly rolling tract of land. The field assigned for forestry experiments is almost level, except for a slight draw which extends diagonally across it (Plate III). The main irrigating ditch which waters a number of farms below, borders the forestry field on one side, the field itself being irrigated by a lateral taken from the ditch at a higher level. The soil is a clay loam, with stiff clay subsoil. It contains so much alkali that few crops would grow in it, though a good crop of beets was produced on a part of the field in 1895, with very little irrigation.

THE PLANTING OF 1896.

Five acres were plowed very deep in the autumn of 1895, and thoroughly harrowed just before planting began, late in April, 1896. It was impossible to get water on the plats for a month after planting, so that the stand was very poor. In August a grasshopper raid destroyed most of the living trees, and three of the plats were abandoned. The remaining plats were reset in the spring of 1897 on a different plan, the varieties originally planted not being available. In replanting, the living trees were not disturbed. Only the two plats thus replanted are reported.

PLAT 1.—*1 acre, 2 by 3 feet, 7,260 trees.*

Original plan:

P M H B O M H B P

E A M A L A B A E

D B H M S B H M D

Wa A B A T A B A Wa

O M H B P M H B O

L A M A E A B A L

S B H M D B H M S

T A B A Wa A B A T

P M H B O M H B P

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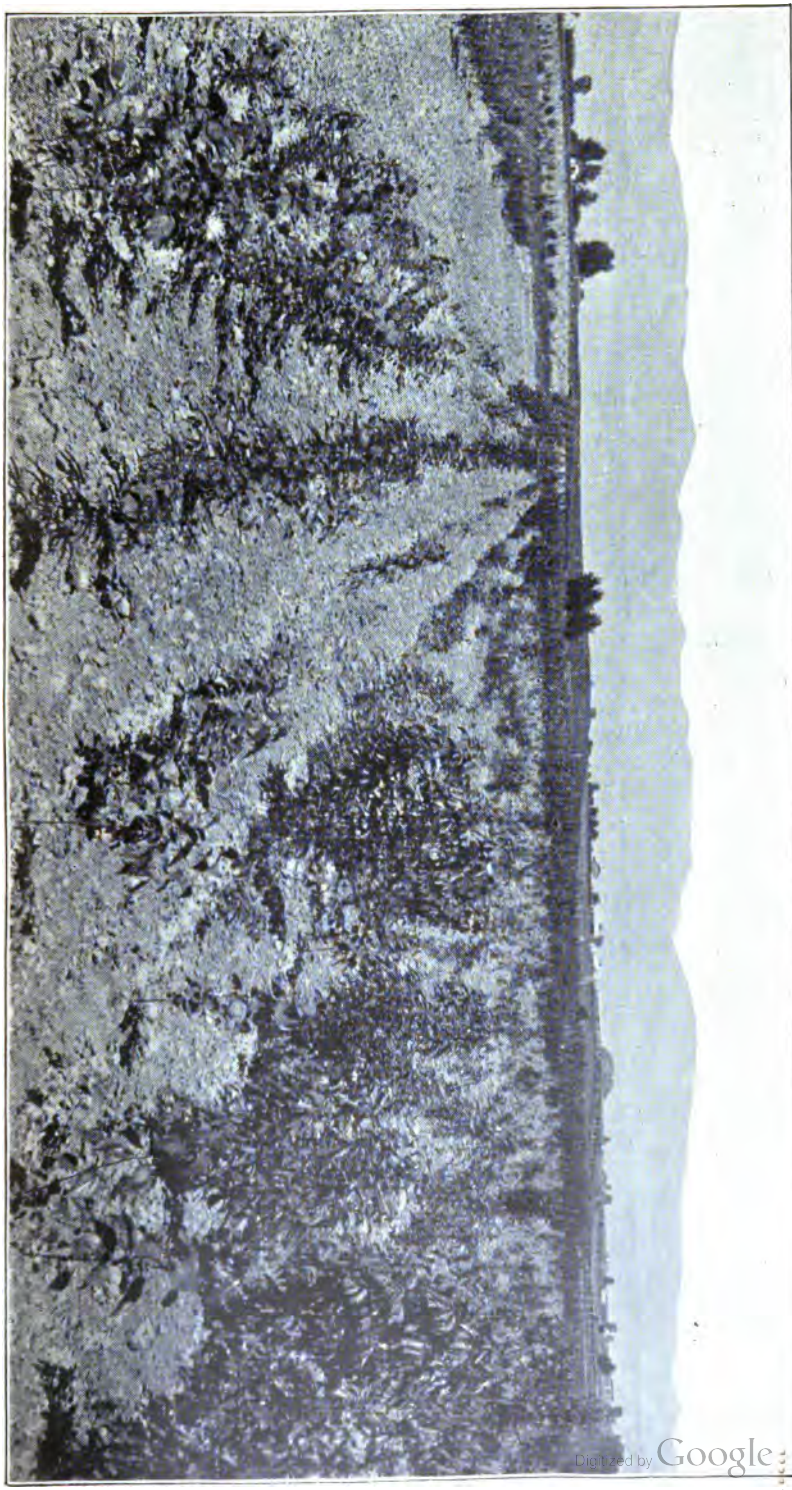

COLORADO.—GENERAL VIEW OF PLANTATION FROM EAST SIDE.

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A—Artemisia	1,815
B—Boxelder	1,361
M—Silver Maple	1,361
E—White Elm	227
H—Honey Locust	907
L—Sweet Birch	227
O—Bur Oak	227
T—Chestnut	227
Wa—White Ash	227
D—Douglas Spruce	227
P—Rock Pine	227
S—Scotch Pine	227

At planting time the Birch, Chestnut, and Boxelder were in very poor condition; all others, good. Stock from same sources as that used elsewhere.

Reports.

June 3, 1896, result of count: 1,815 Artemisia, 1,300 Maple, 72 Boxelder, 700 Honey Locust, 100 Rock Pine, 227 Bur Oak, 227 Elm, 227 Ash, 67 Birch, 0 Chestnut, 41 Black Cherry (substituted), 0 Scotch Pine, 27 Douglas Spruce, or 62 per cent.

October 3, 1896, result of count: 500 Artemisia, 72 Boxelder, 443 Honey Locust, 4 Rock Pine, 71 Bur Oak, 96 Elm, 10 Douglas Spruce, 67 Birch, 41 Cherry. Maple and Ash not reported.

In April, 1897, the plat was replanted as near as possible after the following plan, without disturbing the living trees:

Second planting:

P M P M P

E P H P A

P B P B P

A P P P E

P M P M P

E P H P A

P B P B P

A P P P E

P—Aspen	3,630
B—Birch	908
M—Silver Maple	907
H—Honey Locust	453
E—White Elm	454
A—Green Ash	454

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July 10, 1897, result of count: 1,903 Aspen, 265 Birch, 556 Maple, 213 Elm, 375 Ash, 294 Artemisia, 27 Oak, 297 Honey Locust, 40 Boxelder, 28 Cherry, and 5 Douglas Spruce; or 55 per cent of original number planted.

October 1, 1897, result of count: 278 Artemisia, 279 Elm, 469 Honey Locust, 18 Oak, 4 Douglas Spruce, 36 Boxelder, 26 Cherry, 50 Mulberry, 1,278 Aspen, 71 Birch, 388 Maple, 296 Ash.

The original plan of this plat was designed more to test a great variety of species than to provide suitable light conditions for them, and hence the great loss and necessary replanting with other species will have no especial effect on the purpose in view. As the great preponderance of trees reported living at the end of the growing season in 1896 were light demanding, it was determined to keep the nurse trees of this character in this plat, and in the replanting Aspen and Birch were made the nurse trees. As reported in July, only a little more than one-fourth of the living trees are shade-enduring species.

PLAT 2.—*1 acre, 3 by 3 feet, 4,840 trees.*

Original plan:

M	O	M	Ch	M	HL	M	Ch	M	BL	M	O
B	M	B	M	B	M	B	M	B	M	B	M
M	Ch	M	BL	M	Ch	M	BL	M	Ch	M	BL
B	M	B	M	B	M	B	M	B	M	B	M
M	HL	M	Ch	M	O	M	Ch	M	HL	M	Ch
B	M	B	M	B	M	B	M	B	M	B	M
M	Ch	M	BL	M	Ch	M	BL	M	Ch	M	BL
B	M	B	M	B	M	B	M	B	M	B	M
M	BL	M	Ch	M	HL	M	Ch	M	BL	M	Ch
B	M	B	M	B	M	B	M	B	M	B	M
M	O	M	BL	M	Ch	M	BL	M	Ch	M	O

M—Silver Maple	2,420
B—Jack Pine	1,210
Ch—Black Cherry	581
BL—Black Locust	323
HL—Honey Locust	194
O—Bur and White Oaks	112

All stock was in good condition at planting time.

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Reports.

June 3, 1896, result of count: 2,400 Maple, 700 Jack Pine, 581 Cherry, 323 Black Locust, 150 Honey Locust, 112 Oak.

October 3, 1896, result of count: 1,029 Maple, 66 Pine, 10 Black Locust, 49 Honey Locust, 26 Oak. Cherry not reported.

In April, 1897, the plat was replanted, without disturbing the standing trees, as nearly as possible to the plan here given:

M	B	M	H	M	E
P	M	P	M	P	M
M	E	M	Bi	M	B
P	M	P	M	P	M
M	B	M	H	M	E
P	M	P	M	P	M
M	E	M	Bi	M	B
P	M	P	M	P	M

M—Maple	2,420
P—Aspen	1,210
B—Rock (Bull) Pine (*a*)	302
E—White Elm	302
H—Honey Locust	303
Bi—Birch	303

Reports.

July 10, 1897, result of count: 1,624 Maple, 160 Cherry, 200 Honey Locust, 10 Black Locust, 32 Jack Pine, 620 Aspen, 82 Elm, 109 Birch; or 58 per cent of original planting.

October 1, 1897, result of count: 1,544 Maple, 160 Cherry, 216 Honey Locust, 20 Oak, 10 Black Locust, 25 Jack Pine, 605 Aspen, 150 Elm, 69 Birch.

SOUTH DAKOTA.

The South Dakota Agricultural College, located at Brookings, in the eastern border of the State, began experiments in forest tree planting in 1889. When the Department made its first plantings at this station in 1896, permission was courteously given to use any data which the college plantations might supply, and also to underplant in the college plats. The kindness of the college was the more readily accepted by the writer because of his association with the institution from 1887 to 1891, during which period he planned and personally superintended the planting experiments at the college.

a To be planted hereafter.

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In 1889 ten plats of one-half acre each were planted at this station. In 1890 twelve one-half acre plats were added, and in 1891 eight plats were planted, making a total of 15 acres. The Forestry Division planted six plats in 1896, and seven in 1897, making a total acreage in the grove of 21½ acres. (Plate IV.)

LOCATION AND SOIL.

The plats occupy almost level ground, with a slight rise to the west and south. Just beyond the limits of the plantation, to the west, the land rises to a low ridge, on which the college buildings are located. There was a small Cottonwood "timber claim" one-half mile south of the plantation when the first trees were set, this being the nearest grove of any kind. The site is in the open prairie, the nearest natural woodland being the fringe of trees along the Sioux River, 5 miles to the westward.

The soil is the usual black loam of the prairies, very rich, the surface soil being 18 to 30 inches deep, and separated from the stiff yellow clay subsoil by a thin stratum of coarse gravel mixed with clay. The clay subsoil is of unknown depth.

RAINFALL.

The mean annual rainfall from May, 1888, to December, 1894, was 16.06 inches, as observed at the college. The following record for the growing season of 1892, a year of unusually plentiful rain, and 1894, a season of exceptional drought, fairly presents the extremes of precipitation. The precipitation for the growing season of 1896 and 1897 is also given.

Year.	April.	May.	June.	July.	August.	September.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1892	3.14	7.25	3.52	3.69	3.03	1.49	22.12
1894	3.04	.30	1.30	.09	.73	1.68	7.14
1896	5.55	3.46	3.84	2.10	.44	1.88	17.27
1897	2.45	.83	3.86	4.41	3.59	3.17	18.31

THE PLANTING OF 1889.

A few plats of this planting are given as illustrating the action of well-known species of trees when planted in mixture.

The season of 1889 was very favorable for trees, and a good stand was secured in all the plats. Subsequent years of severe drought have served to test the adaptability of the several species to the locality, and hence this planting is treated in considerable detail.

In plats 1, 2, 6, 7, and 9 several species of Russian Poplar were set and made a vigorous growth the first season, but in the drought years that followed they were almost entirely killed, none of them equaling the common Cottonwood as a drought-resisting plant. In plat 4 White

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FIG. 1.—SCOTCH PINE IN SOUTH DAKOTA PLANTATION.

FIG. 2.—SOUTH DAKOTA PLANTATION.

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Pine was planted 12 by 12 feet apart, with Boxelder for nurse trees, but all were dead by the end of the second year. Larger specimens, planted in the college lawn, lived through several years, making a feeble growth, but all succumbed in the drought of 1894. European Larch and Boxelder were set in one plat, and the Larch made a good stand, but a freeze in May, 1890, when the Larch leaves were half grown, killed a large number of the trees. It required several years for the Larch remaining to form leading shoots, and the best trees in the plantation are now scarcely as high as the Boxelder among which they grow. The species was highly recommended for planting throughout the West a number of years ago, but this experiment does not demonstrate in it any value for this latitude.

The following discussion of plats in this planting is given as illustrating the action of the several species in mixture:

PLAT 1.—*One-half acre, 4 by 4 feet, 1,361 trees.*

B S B C B S

P B P B P B

B C B S B C

P B P B P B

B S B C B S

P B P B P B

B C B S B C

P B P B P B

B—Boxelder.
P—*Populus certinensis* (Russian Poplar).
S—White Spruce (Scotch Pine substituted in one-third of plat).
C—Cottonwood.

The Russian Poplar soon failed largely, and it was replaced the second and third year after planting with Green Ash. The White Spruce were wild seedlings dug in the Black Hills and grown one year in nursery rows, at the college. The Spruce was set at the same time the other trees were, and the weather being favorable a good stand was secured. The first few years the growth was extremely small, but the trees are now (1897) well established and are making vigorous growth in the shade of the Boxelders, which average two to three times their height. In most cases the Boxelder crowns meet over the Spruce, but as yet the latter show no injury from the shading.

The Scotch Pines in this plat are fully equal to those in plat 8, noted below, and the Boxelder and Silver Maple seem to have about the same effect as nurse trees. The Cottonwoods have thinned out consid-

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erably, but those remaining are in good condition and are from 2 to 3 feet taller than the remaining species in the plat.

The Boxelder has proven its excellence as a nurse for this latitude. During the favorable seasons of 1889–1893 it grew rapidly, shading the ground so well that cultivation was unnecessary after the third year from planting. The years 1894 and 1895 were both extremely dry, and the Boxelder showed great injury. In the spring of 1896 the growth of the two previous years was dead, but dormant buds sprouted in the older limbs, and scarcely a tree was entirely killed. The trees averaged 9 feet high at this time, and the drought that checked their growth so severely had much less effect on the more valuable species, so that it served merely to head in the nurse trees. The growth of 1896 was vigorous, thickening the tree crowns and increasing their value as nurses by shading the ground more completely. The dead twigs in the Boxelder tops give the plantation a bad appearance, but the tenacity of life in the species has been well proven, and its usefulness as a nurse tree in high prairie demonstrated.

It may be objected that the wood of the tree is valueless, but if by using it good results in starting conifers and valuable hardwoods can be secured, other considerations may well be ignored.

PLAT 5.—*One-half acre, 4 by 4 feet, 1,361 trees.*

B B B B B B

B O B E B O

B B B B B B

B E B O B E

B B B B B B

B O B E B O

B B B B B B

B E B O B E

B—Boxelder.
O—Bur Oak.
E—White Elm.

In this plat the Boxelder has so completely covered the ground that the leaves of the trees have been prevented from blowing away and already show the formation of humus. Particular interest attaches to this plat by reason of the effect of the nurse trees on the Bur Oak. The natural habit of this tree, when grown in the open, is to branch freely, giving to even the young specimens something of the spreading crown of old trees. In this plat the Oaks are forced straight and tall in proportion to their diameter of trunk. In some cases they now

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approach the nurse trees in height, and without exception the leading branch is well in advance of the laterals, and the trees are making a vigorous growth. Even the few that are entirely shaded (overhead) by the Boxelders are in good condition. The Elms average somewhat taller than the Boxelders in this plat. They show the formative effect of the nurse trees in their straight trunks and high branching.

PLAT 8.—*One-half acre, 4 by 4 feet, 1,361 trees.*

M C M C M C M C

P M C M B M C M

M C M C M C M C

C M P M C M B M

M C M C M C M C

B M C M P M C M

M C M C M C M C

C M B M C M P M

M C M C M C M

P M C M B M C

M—Silver Maple.
C—Cottonwood.
P—Scotch Pine.
B—White Birch.

This plat contains a good stand of Scotch Pine and White Birch, the nurse trees being Silver Maple and Cottonwood. The great majority of the Cottonwoods failed during the drought years of 1894 and 1895, but those which remain are the tallest trees in the plantation. The Birches are second to the Cottonwoods in height, and are the handsomest trees in the entire plantation. They were purchased for Yellow Birch, but proved to be European White Birch. The tree is a native of cool, moist climates, and its vigorous growth thus far is an illustration of the ability of species to succeed under widely varying conditions. The Maples froze back to the ground the first winter, and have since grown with several trunks, which has increased their shade but has not improved their appearance. They have withstood the drought years better than Boxelder, but they have been injured somewhat by sunscald. They do not equal Boxelder as a nurse tree.

The Scotch Pines were bought as seedlings 10 to 12 inches high, and were first planted in nursery rows and heavily mulched. The second spring favorable weather was chosen for setting them in the plat with the other trees. The Pines are unequal in growth, some being almost

as tall as any of the Maples, and the average being about 4 feet less. They are now from 6 to 15 feet high and making vigorous growth. They made much less growth during the drought years, but show no other effect of drought and are in perfect condition. The plat is too open for best results. Green Ash was planted in where the Cottonwoods failed, and in this mixture made very satisfactory growth.

This plat is in the south border of the plantation, and the effects of the wind are especially noticeable on the pines on that side (see Plate IV) which are not only much bent, but are also much shorter than those in the center of the plat, where there is protection.

PLAT 10.—*One-half acre, 4 by 4 feet, 1,361 trees.*

B C A E B C A E

C A E B C A E B

A E B C A E B C

E B C A E B C A

B C A E B C A E

C A E B C A E B

A E B C A E B C

E B C A E B C A

B—Birch.
C—Black Cherry.
A—White Ash.
E—White Elm.

This plat was designed without nurse trees, but the four species were arranged in rows so that the light-demanding Ash and Birch would come between the more shade-enduring Elm and Cherry. All four species are really light demanding, but relatively the Cherry and Elm endure much more shade during youth than the others.

It is generally believed that Boxelder is a more rapid grower than any of the species named, and for the first three years this was true, but after nine years' growth Cherry, Elm, and Birch are larger than Boxelder growing in a plat beside this, and the Ash will average as tall, though not so large otherwise.

This is the best plat in the plantation. The crowns are so dense that weed growth is impossible, and it is difficult to force one's way among the trees, which are all in fine condition. The Birch is about 2 feet taller than the Elm and Cherry, which are of equal height, the Ash averaging about 2 feet less.

The Cherry has hardly yet begun to form a leader. The first three years this species grew in bush form, dividing near the ground into

several branches. As the neighboring trees crowded it the Cherry assumed a more upright habit and a tendency toward one main branch taking the lead, and a trunk is beginning to appear. The Birch is more tree-like, but holds its lateral branches almost to the ground. The Elm parts with its lower branches more readily, and the Ash, having light only at the top by reason of its slower growth, forms few laterals.

Following is a table showing the number of living trees in these plats, one-half acre each, together with diameter and height growth, the count being made in August, 1897:

	Living trees.	Greatest height.	Average height in feet and inches.	Greatest circumference.	Average circumference.
PLAT 1.		*Ft. in.*	*Ft. in.*	*Inches.*	*Inches.*
Boxelder	440	14 0	10 4	10¾	8
Ash	215	16 6	11 6	10¼	6⅜
Russian Poplar	56	20 0	17 3	16	11½
Cottonwood	40	25 0	21 5	21	18⅜
Black Hills Spruce	47	6 4	4 5	4½	3½
Scotch Pine	17	13 0	9 10	12	7¼
Total	815, or 60 per cent of original planting.				
PLAT 5.					
Boxelder	849	16 6	12 6	10	7⅓
Bur Oak	41	11 0	7 9	6	4⅛
White Elm	165	16 0	10 7	9¾	6⅜
Green Ash	113	6 4	4 6	2¼	1⅜
Total	1,168, or 85 per cent of original planting.				
PLAT 8.					
Silver Maple	164	16 6	13 7	11	6⅞
Cottonwood	113	22 6	18 5	19	15½
White Birch	99	19 0	14 0	13½	13½
Scotch Pine	69	15 6	9 6	14½	8½
Green Ash	100	12 0	9 6	6¼	4⅜
Total	545, or 40 per cent of original planting.				
PLAT 10.					
Black Cherry	210	17 6	14 9	15¼	9⅛
White Birch	138	22 0	17 4	20	14⅜
Green Ash	345	15 0	12 0	8¼	5
White Elm	300	18 0	13 1	11½	7⅜
Total	993, or 73 per cent of original planting.				

Circumference 1 foot from the ground.

THE PLANTING OF 1890.

The plats set in 1890 were planted pure—that is, each plat was composed of a single species. In the case of Boxelder and Green Ash plats on opposite sides of the drive were planted, the one with seed sown in hills and the other with 1-year-old seedlings, to determine the relative value of the two methods. The use of seedlings was demon-

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strated to be in every way superior. The Boxelder seed germinated poorly, making an uneven stand, and while in the seed leaf both Boxelder and Ash were much injured by cutworms, which did practically no harm to the opposite plats, where young trees were used.

The seed plants required hand weeding, making cultivation the first year more difficult and expensive, and in the spring of the second year the seed plats had to be thinned to a single tree in the hill, again increasing the cost. A count made at the end of the first growing season (see Bulletin 20, S. Dak. Experiment Station) showed that the seed plat of Boxelder was a failure, while in the seedling plat 83 per cent grew. Of the Green Ash 89 per cent of the seedlings lived, while only 49 per cent of the seed grew.

The following varieties were planted pure: Boxelder, Green Ash, Silver Maple, White Elm, Russian Poplar (*Populus certinensis*). As compared with mixed planting, the disadvantages of pure planting are very apparent in this plantation. The mixed plats in which shade-enduring trees were used as nurses are now so thick as to completely shade the ground, and no cultivation has been necessary in them for four years. The more valuable trees in them, such as Ash and Elm, are in better condition than when planted pure, having been benefited by the side shade of their more densely foliaged neighbors. In the pure-planted Boxelder plats, while the trees have grown quite as well as in mixed planting, they are of themselves of low intrinsic value, and hence when the Boxelders are gone nothing will remain. Used as a nurse, the Boxelder reaches small fuel size, and when it is removed there remains a grove made the more valuable by having used it.

Silver Maple shows the same characteristics, planted pure, except that at Brookings the young trees winterkill and sprout from the crown, thus growing in coppice form. As before stated, the Russian poplar failed during the years of drought.

In the Ash and Elm plats cultivation is still necessary seven years after planting. This fact alone makes the pure planting of these species inadvisable. The trees have not made as tall growth, and are much more forked than the same species in mixed planting. Trees planted in the plains are much more apt to head low than in forest regions because of the intense sunshine and the heavy winds. There is a constant use in western farms for pole timber, and its value is greatly increased by straightness and freedom from knots. If the young trees can be grown free of low branches their timber will be much stronger and more useful for all farm purposes. Hence the great importance of planting varieties the wood of which is useful in farm economy among others which will encourage length of stem and freedom from branching. Quick maturing kinds like Cottonwood and Boxelder may be planted alone where the object is merely to secure a supply of cheap fuel, but even in this case the method is not economical, since it could be accomplished with more durable species in mixture.

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In a plat of Shellbark Hickory mixed with Silver Maple the Hickory (one year old, grown in nursery rows at the college) were all winter-killed the first year, and their places were filled in with Green Ash.

In 1891 4½ acres in various mixture were added to the plantation, but as no new species were included extended notice need not be made of them.

PLANTINGS OF 1896.

Underplanting.

In addition to the 3 acres of new plats made by this division in 1896, plats 18 to 31 (set in 1890 and 1891) were underplanted with conifers. These plats had been replanted the year previously by Professor Corbett with Black Cherry and two-year-old Scotch Pine seedlings. Many blanks yet remained, and although the shade in the plats was too thick to anticipate great success from underplanting, it was believed that even if a slight admixture of conifers resulted, an opportunity would be afforded of watching the development of the conifers, and the value of the plats would be increased.

Since the blanks were irregular it was impossible to plant to a definite plan, but, in general, when a blank occurred in the midst of densely foliaged trees, as where the new tree would be surrounded by Boxelders 10 to 15 feet high, Douglas Spruce, White Spruce, or Jack Pine, was set; where there was more light Scotch Pine or Rock (Bull) Pine was set.

The Douglas Spruce and Rock Pine used were wild seedlings dug in the mountains of Pueblo County, Colo. The Jack Pines were wild seedlings from Carleton, Minn. The Scotch Pines were transplanted nursery-grown trees, 12 to 15 inches, and the remaining trees were nursery-grown seedlings. The roots of the trees were puddled when received, and heeled in in the shade of other trees. In planting, the trees were carried in pails with the roots in the water; they were planted the same depth they stood before, and were well firmed.

Unfortunately, no record was kept of the number of conifers set in each plat. In October, 1896, after the growing season was over, a count of trees showed 560 conifers in plats 18 to 26*a*, and 640 in plats 26*b* to 31. In June, 1897, a count by plats and varieties was made, resulting as follows, each plat containing one-half acre of ground:

Plat 18, 3 Jack Pine and 2 Scotch Pine, 5; plat 19, 22 Jack Pine, 25 White Spruce, 4 Rock Pine, and 22 Scotch Pine, 73; plat 20, 2 Jack Pine, 2 Scotch Pine, and 1 White Spruce, 5; plat 21, 1 Jack Pine, 18 Scotch Pine, and 15 White Spruce, 34; plat 22, 39 Jack Pine, 29 Scotch Pine, 16 Rock Pine, and 9 White Spruce, 93; plat 23, 16 Jack Pine, 14 Scotch Pine, 5 Rock Pine, and 12 White Spruce, 47; plat 24, 19 Jack Pine, 41 Scotch Pine, 16 Rock Pine, and 33 White Spruce, 109; plat 25, 25 Jack Pine, 29 Scotch Pine, 9 Rock Pine, and 19 White Spruce, 82; plat 26*a* (one-fourth acre), 11 Jack Pine, 9 Scotch Pine, 5 Rock Pine, and 11 White Spruce, 36. Totals in plats 18 to 26*a* (4¼ acres), 138 Jack Pine; 166 Scotch Pine; 55 Rock Pine; 125 White Spruce; grand total, June, 1897, 484.

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Plat 22*b* (one-fourth acre), 15 Jack Pine, 20 Scotch Pine, and 23 White Spruce, 58; plat 27, 50 Jack Pine, 51 Scotch Pine, 4 Rock Pine, 36 White Spruce, and 13 Douglas Spruce, 154; plat 28, 40 Jack Pine, 28 Scotch Pine, 1 Rock Pine, 40 White Spruce, and 12 Douglas Spruce, 121; plat 29, 62 Jack Pine, 65 Scotch Pine, 2 Rock Pine, 95 White Spruce, and 53 Douglas Spruce, 277; plat 30, 1 Rock Pine and 8 Douglas Spruce, 9. Totals in plats 26*b* to 30 (2¼ acres), 167 Jack Pine; 164 Scotch Pine; 8 Rock Pine; 194 White Spruce; 86 Douglas Spruce; grand total, June, 1897, 619.

To these figures must be added 99 Scotch Pines underplanted previous to 1896, making a total of 1,201 conifers on 6½ acres, or an average of 185 per acre. Or, leaving out plats 18, 20, and 30, which together have but 19 conifers, there having been very few blanks in these plats when the conifers were set, the 5 acres remaining average 236 conifer trees per acre, a number sufficient to make quite a change in character from the original hard-wood planting. A note accompanies the report to the effect that the trees are growing nicely, some of the pines having made a growth of 1 foot thus far this season (June 15, 1897).

No report of this underplanting was made in the fall of 1897, but a hasty examination made by the writer after a snowstorm in early December showed that the small conifers gave every promise of success.

PLAT PLANTING.

Two series of plats of one-sixteenth acre were designed to illustrate the effects of close and wide spacing, and the trees were set at distances as follows: 1 by 1 foot, 1 by 2 feet, 2 by 2 feet, 2 by 3 feet, 2 by 4 feet, 3 by 3 feet, 3 by 4 feet, 3 by 5 feet, 3 by 6 feet, 4 by 4 feet, 4 by 5 feet, 4 by 6 feet, 5 by 5 feet, 5 by 6 feet, 6 by 6 feet. One series was arranged as a wind mantle, to be placed in the border of the plantation, but through an unfortunate misunderstanding its location was changed, and hence the purpose of the design is defeated. In this series conifers are arranged in continuous rows, and the spaces are filled in with Artemisia, as indicated in the accompanying diagram.

Wind mantle plat, 3 by 3 feet.

D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D
D a a D a a P a a B a a P a a B a a D a a S a a S a a D a a D

a—Artemisia.
D—Douglas Spruce or Red Cedar.
P—Rock Pine.
B—Jack Pine.
S—Scotch Pine.

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Such an arrangement provides for a wind-break 90 feet wide around the outside of the plantation, in which the conifers shall form solid rows, separated the first few years by nurse trees, which should not be permitted to remain long enough to weaken the lower branches of the conifers. Had such a wind-break been placed originally to the south of the Brookings plantation, the damage apparent there could not have occurred.

In the second series of one-sixteenth acre plats, Boxelder was used as a nurse tree, and various hard woods and conifers were intermixed. A few of the plans, with result of count made in the first week in July, are given herewith.

One-sixteenth acre, 1 by 1 foot, 2,722 trees.

O B S B Y B S B L

A P B P A P B P A

S B S B S B S B S

B P A P B P A P B

L B S B C B S B O

A P B P A P B P A

S B S B S B S B S

B P A P B P A P B

O B S B Y B S B L

A P B P A P B P A

B—Boxelder	1,021
A—Artemisia	340
S—White Spruce	510
P—Scotch Pine	680
O—Bur Oak	42
L—Sweet Birch	43
Y—Yellow Birch	43
C—Black Cherry	43

In this plat it was the purpose to secure a close stand of conifers and to avoid all cultivation. The Boxelder was designed to shade the soil, and thus prevent weed growth until the conifers were well rooted, when it was to be cut out. It was found necessary to hoe the plat twice, despite the close planting. The count resulted: 864 Boxelder, 375 Artemisia, 139 White Spruce, 16 Scotch Pine, 10 Cherry, and 14 Oak, or 52 per cent of a perfect stand. It will be noted that the count reveals more Artemisias than the plat calls for; doubtless through an error in planting.

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One-sixteenth acre, 1 by 2 feet, 1,361 trees.

C B D B P B

B Ba B Ba B Ba

D B P B D B

B Ba B Ba B Ba

P B D B C B

B Ba B Ba B Ba

D B C B D B

B Ba B Ba B Ba

C B D B P B

B—Boxelder	681
Ba—Jack Pine	340
C—White Spruce	85
D—Douglas Spruce	85
P—Scotch Pine	170

As in the last plat, the purpose was to secure a close stand of conifers, using Boxelder as a protection only until they could become established. The count resulted: 657 Boxelder, 137 Jack Pine, 94 White Spruce, 24 Douglas Spruce, 50 Scotch Pine, or 70 per cent.

One-sixteenth acre, 2 by 2 feet, 681 trees.

B B B B B

L B P B L

B B B B B

P B C B P

B B B B B

L B P B L

B B B B B

P B C B P

B—Boxelder	511
P—Rock Pine	75
L—Sweet Birch	48
C—Black Cherry	47

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Result of count: 507 Boxelder, 41 Cherry, 12 Rock Pine, and 0 Birch, or 82 per cent. It was found that the cultivation necessary in the first year after setting in such close plantings is quite as expensive as when the trees are set 3 by 3 feet, since hand labor is necessary, whereas in the wider spacing all the work can be done by horse cultivator. The extra expense of setting and the value of the material fully offset the advantage gained by saving in cultivation after the first year, so that such close planting would not seem advisable.

The total of trees standing in the one-sixteenth-acre plats, as reported June 30, 1897 (the blanks in these plats having been sown with the seed of Oaks, Walnuts, and Hickories), is as follows: 2,738 Artemisia, 2,620 Boxelder, 231 Black Cherry, 138 Bur Oak, 15 Black Walnut, 143 Douglas Spruce, 428 Jack Pine, 67 Rock Pine, 388 White Spruce, and 210 Scotch Pine; total 6,978, or at the rate of 5,582 trees per acre.

On October 1, 1897, the one-sixteenth-acre plats contained a total of 2,347 Artemisia, 2,607 Boxelders, 235 Black Cherry, 150 Oak and Walnut, 307 Douglas Spruce, 241 White Spruce, 42 Austrian Pine, 342 Jack Pine, 156 Scotch Pine, 154 Rock Pine, 4 Birch, or 6,585 trees.

Two one-half-acre plats were set at this station in 1896, in neither of which a good stand was secured, owing to hot south winds during and immediately following the planting season.

PLAT 33.—*One-half acre, 4 by 4 feet, 1,361 trees.*

A P A S A P

B A B A B A

A S A P A S

B A B A B A

A P A S A P

B A B A B A

A S A P A S

B A B A B A

A—Boxelder	681
B—Jack Pine	340
P—Rock Pine	170
S—Scotch Pine	170

(Bur Oak was substituted for one-half the Rock Pines.)

This plat is designed to illustrate the relative light requirement of the three Pines, the Boxelder to stand only until the Pines are established. The very unfavorable weather at planting time and immediately following resulted in a very poor stand.

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Reports.

Result of count October 21, 1896: 223 Boxelder, 243 Jack Pine, 40 Scotch Pine, 35 Rock Pine, and 38 Bur Oak.

In the spring of 1897 the blank places in the plat were set with Scotch and Austrian Pine. A count made June 30, 1897, resulted: 227 Scotch Pine, 343 Austrian and Jack Pines (the workman could not distinguish between the young plants of these species), and 222 Boxelder. No Oak nor Rock Pine reported.

PLAT 34.—*One-half acre, 3 by 3, 1,361 trees.*

O W E W O W

E E E E E E

W B W B W B

E E E E E E

O W E W O W

E E E E E E

W B W B W B

E E E E E E

O W E W O W

E—White Elm	767
W—White Spruce	340
B—Jack Pine	170
O—Bur Oak	84

In planting a few Scotch Pine, Black Cherry, and Douglas Spruce were substituted for Elm and Jack Pine. In this plat White Elm and Jack Pine are designed as nurse trees for White Spruce and Oak. The mixture will require a longer period of cultivation than if a quick-growing tree like Boxelder had been used, but in the end it may prove an advisable mixture, since the Elms are more tenacious of life than the Boxelders.

Reports.

Result of count October 15, 1896: 343 Elm, 197 Jack Pine, 219 White Spruce, 79 Bur Oak, 61 Scotch Pine, 36 Black Cherry, and 12 Douglas Spruce, or 70 per cent of the number planted.

In the first week of May, 1897, all the blanks in this plat were set with Elm, Scotch Pine, and Austrian Pine. On June 30, 1897, a count resulted: 521 Elm, 241 Scotch Pine, 115 Austrian Pine, 77 White Spruce, and 42 Oak (Jack Pine and Cherry not reported).

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Following the general plan pursued in Nebraska and Kansas, the plats set in 1897 were designed with light-demanding species as nurse trees for conifers. Eight one-half acre plats were planted with Artemisia, Aspen, and Birch, both pure and in mixture, and in all blanks were left at regular intervals for the conifers, which will be set in 1898 or 1899, according to the growth of the nurse trees. As these designs are similar to those already given, they do not appear here. Along the north side of the plantation three one-half acre plats were designed as a protection for the remainder of the plantation, and the designs follow:

PLAT 58.—*One-half acre, 3 by 3 feet, 2,420 trees.*

[Rows run east and west.]

A A A A A A A A
P R P R P R P R
A A A A A A A A
R L R L R L R L
A A A A A A A A
P R P R P R P R
A A A A A A A A
R L R L R L R L
A A A A A A A A
P R P R P R P R
A A A A A A A A
R L R L R L R L
A A A A A A A A
P S P R P S P R
A A A A A A A A
S L R L S L R L

Throughout to south side of plat.

A—Artemisia	1,210
P—Aspen	303
L—American Larch	302
R—Red Cedar	369
S—Scotch Pine	236

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Report of count, June 30, 1897: 849 Artemisia, 108 Aspen, 199 Red Cedar, 203 Larch, 79 Scotch Pine, and 88 Elm (substituted), or 63 per cent of planting.

The count of October 1, 1897, resulted: 80 Artemisia, 139 Scotch Pine, 55 Aspen, 95 Red Cedar, 139 Larch, 44 Elm, and 66 miscellaneous substitutes, or 65 per cent of the number planted.

In this plat and those which follow the permanent trees (the conifers) are arranged to form rows running east and west. On the north or windward side Red Cedar forms the border, alternating with Aspen or Larch; 40 feet from the margin of the plantation Pines are set in place of part of the Larch and Cedar. The Cedars are very tough and are especially useful as windbreaks. The Larch may be cut out when large enough for posts, leaving the Cedar and Pine as the permanent species.

In plat 59 Austrian Pine will be used in place of Scotch Pine, and in plat 60 Rock Pine will be used. In plats 44 and 61 the same method of planting is followed, except that the rows run north and south, these plats being on the east side of the plantation. The count of all the plats planted in the spring of 1897, made June 30, gave an average stand of 71 per cent. The stand would have been much better, but the Birch and Cottonwood had started growth before planting was completed.

UTAH.

The first plantings were made at the Utah State Agricultural College, at Logan, in the spring of 1897. The college farm is located on a high bench overlooking a broad valley, and extends to the high and steep foothills of the mountains. The land set aside for forestry experiments is almost level, and lies opposite the mouth of the Logan River Canyon and one-half mile from it (Plate V). The soil is a stiff clay loam, very productive under irrigation, and underlaid with a gravel subsoil, the gravel being of great depth and slightly intermixed with clay. The plats at Logan are of 1 acre each, but for this first planting they have each been divided into two equal parts to permit of experimenting in planting at different distances apart. Hereafter the plats will be planted at uniform distances 3 by 3 or 4 by 4 feet. In this planting both light-demanding and shade-enduring species have been used as nurse trees, and an opportunity is thus given of studying these methods of mixture in plats of the same age.

The hard woods used were all of one-year-old seedlings, except Birch, which was two to three years. None of this stock was in first-class condition, all having been more or less injured in transit. The coniferous stock was planted in nursery beds, from which it will be set in the plats, as designed, when well rooted.

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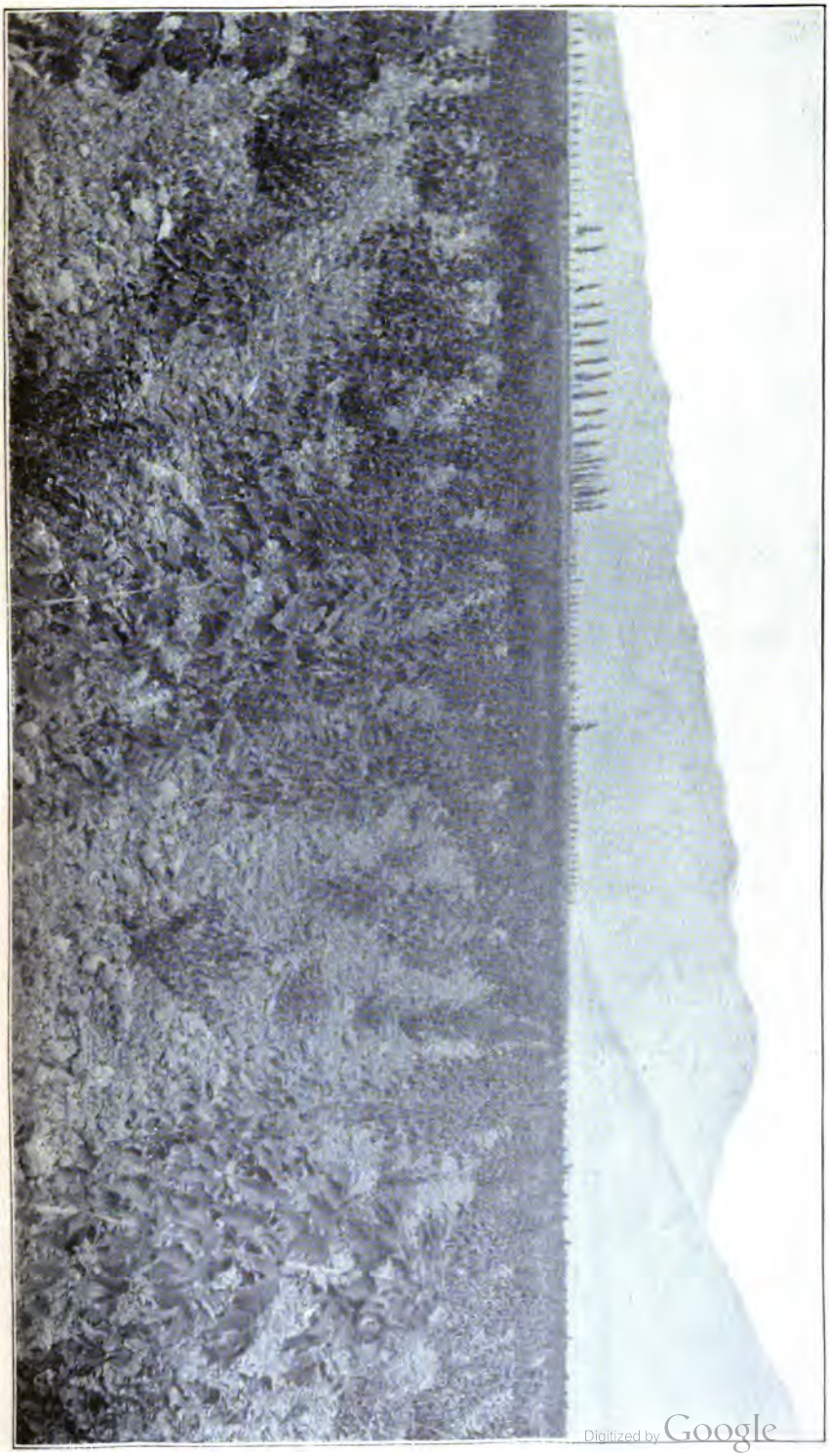

UTAH PLANTATION.

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PLAT 1.—*One-half acre, 2 by 2 feet, 5,445 trees.*

B P B P P P B P B
P P P P P P P P P
P P E P B P L P P
P P P P P P P P P
B P B P P P B P B
P P P P P P P P P
P P F P B P C P P
P P P P P P P P P
B P B P P P B P B

P—Aspen	4,424
B—Birch	681
E—White Elm	85
F—Green Ash	85
L—Honey Locust	85
C—Catalpa	85

Report.

June 30, 1897. This being but a fraction of half an acre, the full quantities noted were not planted. Result of count: 2,129 Aspen, 283 Birch, 49 Elm, 50 Ash, 50 Honey Locust, and 47 Catalpa.

October 1, 1897. Result of count: 1,987 Aspen, 238 Birch, 49 Elm, 45 Ash, 50 Honey Locust, 47 Catalpa.

PLAT 3.—*One-half acre, 2 by 3 feet, 3,630 trees.*

P A P A P A
M C M Pi M C
P A P A P A
M S M C M S
P A P A P A
M C M Pi M C
P A P A P A
M S M C M S

P—Aspen	907
M—Russian Mulberry	908
A—Artemisia	907
C—Catalpa	454
S—Douglas Spruce	227
Pi—Scotch Pine (*a*)	227

a To be planted hereafter.

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This plat is designed with Spruce and Pine as the permanent trees, the nurses being a mixture of light-needing (Aspen and Artemisia) and shade-enduring kinds (Russian Mulberry). The Mulberry, aided by the Catalpa, will change the conditions of light very materially from what they would be with only the Aspen and Artemisia as nurses.

Result of count, June 30, 1897: 576 Aspen, 548 Mulberry, 532 Artemisia, 163 Catalpa, and 105 Douglas Spruce.

The count of October 1, 1897, resulted: 553 Aspen, 550 Mulberry, 540 Artemisia, 159 Catalpa, 72 Douglas Spruce, or 55 per cent of the number planted.

PLAT 2.—*One-half acre, 2 by 4 feet, 2,722 trees.*

B W B S B C B D

a a a a a a a a

P B P B P B P B

a a a a a a a a

B C B D P W B S

a a a a a a a a

P B P B P B P B

a a a a a a a a

B W B S B C B D

a—Artemisia	1,361
B—Birch	681
P—Aspen	340
C—White Fir (*a*)	85
W—White Spruce (*a*)	85
D—Douglas Spruce (*a*)	85
S—Scotch Pine (*a*)	85

In this plat Artemisia is designed merely to fill in for a few years, and when it is cut out the trees will stand 4 by 4 feet apart, with Birch and Aspen as nurses. The conifers are all shade enduring except the Pines, and once established the mixture should be successful.

The count of June 30 resulted: 1,102 Artemisia, 318 Birch, and 374 Aspen (part substituted for Birch).

Count of October 1, 1897: 1,104 Artemisia, 270 Birch, 331 Aspen, or 71 per cent.

a To be planted hereafter.

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PLAT 4.—*One-half acre, 3 by 4 feet, 1,815 trees.*

A R A C A D A H A

E A R A F A D A E

A C A D A H A R A

R A F A D A E A R

A D A H A R A C A

F A D A E A R A F

A H A R A C A D A

D A E A R A F A D

A R A C A D A H A

E A R A F A D A E

A—Artemisia	907
F—Green Ash	113
E—White Elm	113
C—Hardy Catalpa	114
H—Honey Locust	114
R—Red Cedar (*a*)	227
D—Douglas Spruce (*a*)	227

In designing this plat Silver Maple was used as the nurse tree, but stock ordered was not received, so that Artemisia had to be used, changing the character of the plat. The permanent trees are a mixture of shade-enduring conifers, Red Cedar, and Douglas Spruce, with hard woods whose light requirement is in the following order: Honey Locust (most light), Green Ash, White Elm, Hardy Catalpa.

The count of June 30 resulted: 700 Artemisia, 25 White Elm, 42 Green Ash, 27 Catalpa, and 33 Honey Locust.

On October 1 the plat contained 697 Artemisia, 17 Elm, 42 Ash, 30 Catalpa, 23 Honey Locust, or 60 per cent of the number planted.

a To be set hereafter.

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PLAT 5.—*One-half acre, 3 by 3 feet, 2,420 trees.*

B O B D B E B D B O

M B M B M B M B M B

B S B P B D B P B S

M B M B M B M B M B

B A B D B E B D B A

M B M B M B M B M B

B S B P B D B P B S

M B M B M B M B M B

B O B D B E B D B O

M B M B M B M B M B

B—Boxelder	1,210
M—Russian Mulberry	605
E—White Elm	76
O—White Oak	38
A—Green Ash	38
D—Douglas Spruce (*a*)	227
P—Rock Pine (*a*)	151
S—White Spruce (*a*)	75

This plat is designed strictly on the principle of having the great mass of the trees of shade-enduring species. The nurse trees, Boxelder and Russian Mulberry, are both shade-enduring while young, and when they have been cut out the light-demanding species, Pine, Oak, Ash, and Elm, are only equal in number to the shade-enduring Spruces. Where the time spent in cultivation of trees is an important item, as it usually is with the farmer, the use of shade-enduring species as nurses is economical, because the ground is sooner shaded and the period of cultivation is shortened.

Result of count, June 30, 1897: 829 Boxelder, 459 Russian Mulberry, 33 Oak, 34 Ash, and 51 Elm.

On October 1 the plat contained 793 Boxelder, 482 Mulberry, 23 Oak, 34 Ash, 50 Elm, or 70 per cent of the number planted.

a To be planted hereafter.

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PLAT 6.—*One-half acre, 3 by 5 feet, 1,410 trees.*

O R L R O R

P P P P P P

D E S A D E

P P P P P P

L R C R L R

P P P P P P

D A S E D A

P P P P P P

O R L R O R

P—Aspen	705
A—Green Ash	88
E—White Elm	88
L—Black Locust	88
C—Catalpa	44
O—White Oak	44
R—Red Cedar (*a*)	177
D—Douglas Spruce (*a*)	88
S—White Spruce (*a*)	88

This plan provides for a mixture of three shade-enduring conifers with hard woods, the light-demanding Aspen being used as a nurse. At the distance of 3 by 5 feet a much longer period of cultivation will be required than if the trees are planted 3 by 3 feet, but it is claimed that the trees will die out much sooner at the closer planting.

On June 30 a count of trees showed 656 Aspen, 35 Oak, 33 Catalpa, 84 Black Locust, 61 White Elm, and 61 Green Ash.

The count of October 1 resulted: 633 Aspen, 29 Oak, 27 Catalpa, 72 Black Locust, 64 Elm, 41 Ash, or 82 per cent of the number planted.

a To be planted later.

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PLAT 9.—*One-half acre, 3 by 6 feet, 1,210 trees.*

B D B C B

P B R B P

B C B D B

S B A B S

B D B C B

P B R B P

B C B D B

S B A B S

B—Birch	605
P—Rock Pine (*a*)	76
A—Austrian Pine (*a*)	75
R—Red Cedar (*a*)	76
C—White Fir (*a*)	151
D—Douglas Spruce (*a*)	151
S—White Spruce (*a*)	76

In this plat Birch was set 6 feet apart both ways to make a shelter for conifers, which are to be planted when the Birch has grown enough to protect them. The conifers are so arranged that one-fourth of them (the Pines) are light-demanding, and three-fourths are shade-enduring. Unfortunately, the Birch has grown poorly, only 326 being alive on June 30. On account of the wide spacing, it will be necessary to replant the Birches before the conifers can be set.

PLAT 7.—*One-half acre, 4 by 4 feet, 1,361 trees.*

B B B B B B B B

B O B L B O B A

B B B B B B B B

B E B A B E B L

B B B B B B B B

B O B L B O B A

B B B B B B B B

B E B A B E B L

B B B B B B B B

a To be planted hereafter.

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B—Boxelder	1,021
O—Oak	85
E—White Elm	85
A—Green Ash	85
L—Black Locust	85

In this plat, of hard woods exclusively, three-fourths of the trees are of the shade-enduring Boxelder and the remainder are light-demanding species, some of which—notably the Locust—come to usable size so much sooner than the others that it is believed they can be cut out before the slower-growing forms will be overcrowded by them.

The count of June 30 resulted: 781 Boxelder, 63 Oak, 73 Elm, 73 Ash, and 70 Locust. On October 1 the plat contained 733 Boxelder, 45 Oak, 73 Elm, 75 Ash, 70 Black Locust, or 73 per cent of the number planted.

PLAT 8.—*One-half acre, 4 by 5 feet, 1,089 trees.*

B O B H B E B L

M B M B M B M B

B A B L B A B H

M B M B M B M B

B E B H B O B L

M B M B M B M B

B A B L B A B H

M B M B M B M B

B O B H B E B L

B—Boxelder (Artemisia substituted in part)	545
M—Russian Mulberry	272
A—Green Ash	68
L—Black Locust	68
H—Honey Locust	68
O—Oak	34
E—White Elm	34

Result of count, June 30: 281 Boxelder, 134 Artemisia, 228 Mulberry, 21 Oak, 34 Elm, 63 Ash, 50 Black Locust, and 56 Honey Locust.

On October 1 the plat contained 278 Boxelder, 132 Artemisia, 228 Mulberry, 17 Oak, 36 Elm, 62 Ash, 48 Black Locust, 52 Honey Locust, or 78 per cent of the total number planted.

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PLAT 10.—*One-half acre, 4 by 6 feet, 908 trees.*

L O L H L O
C A C A C A
M L M L M L
C A C A C A
L C L C L C
C A C A C A
M L M L M L
C A C A C A
L O L H L O

C—Catalpa 275
A—Artemisia 227
M—Russian Mulberry 113
L—Black Locust 227
O—Oak 28
H—Honey Locust 28

Result of count, June 30: 136 Catalpa, 227 Artemisia, 71 Mulberry, 161 Black Locust, 5 Oak, 43 Honey Locust, and 39 Ash. (As this was the last plat planted, substitutions had to be made on account of varieties not holding out; hence the appearance of new varieties in the count.)

On October 1 the plat contained 130 Catalpa, 130 Artemisia, 53 Mulberry, 129 Black Locust, 2 Oak, 32 Honey Locust, or 52 per cent of the number planted.

GROWTH OF TREES PLANTED AT LOGAN.

During the last week in July measurements of growth were made in the plats, resulting as given in the table below. The figures are the length of new wood produced during the year up to that date. Growth had not yet ceased, so that the figures do not represent the full growth of the year.

Variety.	Largest growth.	Average growth.	Variety.	Largest growth.	Average growth.
	Inches.	*Inches.*		*Inches.*	*Inches.*
Honey Locust	20	9	Oak	5	2
Green Ash	19	10	White Fir	.....	.....
White Elm	22	13	White Spruce	.....	.....
Black Locust	35	18	Douglas Spruce	3	2
Russian Mulberry	24	15	Rock Pine	.....	.....
Boxelder	40	37	Austrian Pine	4	2
Catalpa	21	11	Red Cedar	6	4
Artemisia	52	42	Scotch Pine (seedlings)	4	2
Aspen	38	18	Scotch Pine (transplants)	5	2
Yellow Birch	14	7			

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MINNESOTA.

The State University of Minnesota, in addition to the seat of the experiment station at St. Anthony Park, supports two substations or experiment farms, one in the prairies of the Red River Valley at Crookston, the other in the pineries at Grand Rapids. Land for forestry experiments has been set apart at both substations, the plat at Crookston to be devoted to plantings similar to those at the other stations, and the one at Grand Rapids to be used for replanting cut-over pine lands and to illustrate improved methods of forest management.

CROOKSTON PLANTATION.

The land set aside for forest plats at the Crookston experiment farm is the typical prairie of the Red River Valley, one of the most famous wheat-producing regions of the world. The soil is a rich clay loam, black, with very fine sand, underlaid with a stiff clay subsoil within 2 to 3 feet of the surface. This subsoil is not readily permeable by water, as is evidenced by the great number of pools that dot the valley in a wet season. The experiment farm is rather lower and not so well drained as the average valley land, and the forest land includes some of the best and some of the poorest parts of the farm.

The plantings of 1897 include five 1-acre plats. In two plats a part of the land had been broken the year before and had never produced a crop. The trees were set in "back setting"—that is, the land was broken in the summer of 1896, and in the spring of 1897 it was cross plowed a few inches deeper than the original breaking. It was then well harrowed before planting. The plowing was not more than 4 inches deep in this new land, and was not more than 8 inches deep in the old land.

None of the trees were set, unfortunately, until they had begun to leaf out, the Aspen leaves being fully a half inch in diameter when the plants were set.

Owing to the late planting and dry weather immediately following, a very poor stand was secured and all the plats will have to be replanted next year. Plans and reports of stand are therefore not given.

GRAND RAPIDS PLANTATION.

At the Grand Rapids station a conifer nursery was planted, and about 1 acre of cut-over pine land was reset to Red Pine and White Pine, nursery-grown seedlings of both species being used.

The Grand Rapids experiment farm is located about 2 miles from the town of that name, near the Mississippi River, about 150 miles northwest of Duluth, Minn. The region was formerly covered by extensive pine forests of the first commercial importance, but the pines have been largely cut away, leaving isolated pieces of uncut pine, surrounded by

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extensive areas of cut-over lands, from which the pine has been removed. These cut-over lands are covered with a low growth of Birch and Aspen, with a few other hard woods intermixed, among which are occasionally young pines, their number and species dependent on the proximity of uncut areas.

The soil of the region is a sandy clay loam, varying greatly in character within limited areas. The better soils are being cultivated, but throughout the region there are tracts too poor for cultivation, and these, having once produced a crop of pine, may be reforested, and thus be made measurably profitable. Left without care, the cut lands produce, first of all, a dense growth of Aspen, Birch, Alder, and other hard woods in less numbers. After a time, depending largely upon the proximity of seedling pine trees, young pines appear in this forest cover, and if fire is kept out these seedlings will undoubtedly develop into merchantable trees; but in thus leaving the land to nature there is apt to be either a very poor stand of pines or an uneven stand, or undesirable varieties may gain the ascendancy, while in any case the danger of fire is constant.

An effort will be made at the Grand Rapids station to demonstrate the best methods of growing pine on cut lands. Various methods will be tried and different species will be employed, both pure and in mixture. Owing to the lateness of the season when arrangements were completed for work at this station, only a small plat was planted in 1897.

Underplanting.

In one corner of a large field from which the merchantable timber had been cut several years before, 1 acre was roughly staked off and planted to Red Pine and White Pine without disturbing the soil cover. The natural growth consisted of young Aspen, Birch, and Alder, from 4 to 8 feet high, growing principally in clumps, with narrow grass-covered openings among them. A few seedling White Pines, 5 to 15 inches high, were found scattered among the hard woods, and toward one side of the plat was a group of vigorous pines about 40 years old, of both Red and White species. Jack Pine 50 feet high was also growing in the immediate vicinity, and there were a few mature Aspens and Birches. While the growth was sufficient to make quite a dense shade over the greater part of the area, it was not shady enough to prevent grass, and the few wild White Pine seedlings were in fine condition.

The stock that was planted in had been received from nurseries and planted in nursery rows a few weeks before, and of course this second moving was not beneficial. The seedlings were 8 to 10 inches high and in good condition when received. They were planted with a spade, without disturbing the existing growth, approximately 4 by 6 feet apart. One thousand Red (Norway) and 500 White Pine were set. On July 15 a count showed 680 Red (68 per cent) and 414 White (83

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per cent) Pine living. This gives promise of a good stand. If half the trees reported living become thoroughly established and evenly distributed over the acre it will insure a full stand of pine at the age of 25 years, supposing the trees are protected from overcrowding by the natural growth.

Under favorable conditions it is safe to assume that pines set 8 by 8 feet in cut-over lands will make a good stand. This would require 680 trees per acre. So much depends, however, on care of stock, skillful planting, atmospheric and soil moisture at planting time and during the first season, and density of existing growth that it would be much safer to plant 6 by 6 feet apart, or at the rate of 1,210 trees per acre.

In this connection it may be stated that an experiment of a similar nature has been undertaken in the planting of deforested pine lands of Pennsylvania, Mr. N. T. Arnold, of Ridgway, Elk County, having kindly offered the use of land for this purpose. The first planting was made at Ridgway in November, 1897, and a report can not therefore be included in this bulletin.

EXPERIMENTS WITH NURSERIES FOR EVERGREENS.

At each of the stations small evergreens were planted in nursery rows or in shaded beds, preparatory to setting them in the plats later. The plantings were practically a failure at all the stations save Grand Rapids, Minn., which is within the natural pineries. The poor stand secured is the result of several causes.

The methods employed in transplanting evergreens at the leading commercial nurseries are so simple that it would seem easy to put them into practice. The seedling trees are taken from the seed bed, or the young transplants from the nursery rows, care being taken to protect the roots from drying. A furrow is opened with plow or spade, the seedling is placed against the straight side of the furrow at just its former depth, and the earth is drawn up over the roots by the planter, who thus passes quickly along the row on his knees, doing all the work by hand. A second man follows with a block of wood, with which he tamps the soil firmly on the root, and a third man levels up the ground, leaving the surface soil loose, to act as a mulch. Sometimes the entire work is done by one man, but the process is usually and more expeditiously done as above described. Great difficulty was experienced in getting the workmen to follow these simple instructions. Either the trees would be set too deep or the soil would not be well packed about the roots, or the roots would be exposed needlessly while planting, any one of which causes is sufficient to kill the trees. The professors and foremen in charge of the work did everything in their power to have it properly done, but with inexperienced men it was impossible to secure the best planting.

While poor workmanship must be held responsible for a share of fail-

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ure, the principal difficulty must be attributed to the climate. Not only is the soil of the plains more compact and less moist than that of the lake region, where most of the large evergreen nurseries are located, but the air of the West is much drier, and there are almost constant winds which increase evaporation. The newly planted trees are thus subjected to much more severe conditions than those under which they were grown. Under the most favorable conditions of transplanting there is apt to be a greater loss in conifers than in hard woods, and in the case of seedling evergreens that are shipped long distances to dry climates heavy losses are not surprising.

In some cases the trouble began at the nurseries, where the stock was not sufficiently protected from the air while the trees were being dug and packed, and where the packing was so loosely done that the trees dried badly in transit. One shipment was made so late that the trees sprouted badly in the boxes, and the delicate young growth withered on exposure to the light.

Very few of the Western commercial nurseries beyond the immediate influence of the Great Lakes attempt to grow conifers from the seed, having learned from experience that it is more profitable to buy the young seedlings. Beyond the Missouri the difficulties of nursery care for conifers are so much increased that it is the almost universal practice of nurserymen to purchase their evergreen stock as needed for orders.

These facts do not show that the evergreens are unsuitable for planting in the plains, but they emphasize the difficulty of securing a good start. The trees once established are as easily cared for and quite as sure of success as any of the broad-leafed species, perhaps even surer. With favorable conditions at planting time and during the first season, the majority of conifers will become so well established as to withstand as great vicissitudes as the hard-wood trees. Like the hard woods, their rate of growth will be affected by the season, but the record of the Scotch Pine and the White Spruce at Brookings station indicates that the trees are fully as well adapted to that location as are any of the species tested there. At many localities in the plains conifers are growing well. It is evident, therefore, that once a successful method of bringing the trees through the first few years is discovered, the principal difficulty in coniferous planting will have been met.

When the stock was received at the several stations, the roots were well puddled and the stock was carefully heeled in, in a shady place, to await favorable weather for transplanting. Moist, cloudy weather, with fresh soil, are the best conditions for transplanting, but these conditions can rarely be commanded in the West, and in some cases, after waiting as long as possible for good weather, it became necessary to plant the trees during bright days, in rather dry soil. A continuance of clear weather resulted in constantly increasing dryness, so that many of the trees died before rain came. The men had been carefully

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